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MATHEMATIK

ÜBER DIE LOKALISOMETRISCHEN ANALYTISCHEN ABBILDUNGEN

Von B. FUCHS

(Vorgelegt von I. M. Vinogradow, Mitglied der Akademie, d. 16. IV. 1938)

1. Es sei $\mathfrak{B}$ ein schlichtes Gebiet des Raumes von n komplexen Veränderlichen $z^1, z^2, \ldots, z^n$ $(z^k = x^k + iy^k)$. Nach Bergmann kann man (im Zusammenhang mit gewissen Minimalaufgaben) die s. g. Kernfunktion $K(z, \bar{z}) = K(z^1, \ldots, z^n, \overline{z^1}, \ldots, \overline{z^n})$ des Gebietes $\mathfrak{B}$ einführen (1), und mit ihrer Hilfe eine, den pseudokonformen Abbildungen gegenüber invariante Metrik

$$ds^2 = T_{m\bar{k}}\, dz^m\, d\overline{z^k}; \quad T_{m\bar{k}} = \frac{\partial^2 \lg K}{\partial z^m\, \partial \overline{z^k}} \tag{1}$$

aufstellen. [(1) stellt eine positiv definite Hermitesche Form dar; unter einer pseudokonformen Abbildung versteht man eine umkehrbar eindeutige Abbildung von $\mathfrak{B}$ durch n in $\mathfrak{B}$ analytischen Funktionen $w^k = f^k(z^1, \ldots, z^n)$.]

Es sei weiter $\mathfrak{B}^*$ ein schlichtes Gebiet im Raume der Veränderlichen w^k; $K^*(w, \bar{w})$ sei die Kernfunktion des Gebietes $\mathfrak{B}^*$. Durch die Form

$$ds^2 = S_{m\bar{k}}\, dw^m\, d\overline{w^k}; \quad S_{m\bar{k}} = \frac{\partial^2 \lg K^*}{\partial w^m\, \partial \overline{w^k}} \tag{2}$$

wird in $\mathfrak{B}^*$, analog (1), eine invariante Metrik definiert. Wir nennen $w^k = f^k(z^1, \ldots, z^n)$ eine lokalisometrische Abbildung des Bereiches $\mathfrak{B}$ bezüglich des Punktes $M(a^1, \ldots, a^n)$ auf den Bereich $\mathfrak{B}^*$ bezüglich des Punktes $P(b^1, b^2, \ldots, b^n)$, wenn diese Abbildung den Punkt M in P überführt und eine Umgebung von M auf eine Umgebung von P so pseudokonform abbildet, dass

$$S_{m\bar{k}} = T_{q\bar{r}}\, \frac{\partial z^q}{\partial w^m}\, \frac{\overline{\partial z^r}}{\partial \overline{w^k}} \tag{3}$$

ist.

Die pseudokonforme Abbildung des Bereiches $\mathfrak{B}$ auf $\mathfrak{B}^*$ ist ein Spezialfall der lokalisometrischen Abbildung. Hier werden Kriterien für die Existenz solcher Abbildungen gegeben.

2. Die üblichen Bedingungen für die Äquivalenz der Formen (1) und (2) sind die Integrabilitätsbedingungen von (3). Die letzeren bestehen

aus unendlich vielen Gleichungen. Zu unseren Resultaten gelangen wir mit Hilfe der s. g. representativen Koordinaten ([2], [3]). Es seien

$$u^k = T^{k\bar{r}}_{(M)} \frac{\partial \lg M(z, \bar{a})}{\partial \bar{a}^r}; \quad v^k = S^{k\bar{r}}_{(P)} \frac{\partial \lg M^*(w, \bar{b})}{\partial \bar{b}^r} \tag{4}$$

die representativen Koordinaten in $\mathfrak{B}$ und $\mathfrak{B}^*$ bezüglich der Punkte M, P. $M(z, \bar{a}) = K(z, \bar{a}) / K(a, \bar{a})$ ist hier die Minimalfunktion ([1]) von $\mathfrak{B}$ und $M^*(w, \bar{b})$ — die von $\mathfrak{B}^*$. Der Index (M) [bzgl. (P)] weist darauf hin, dass der Wert der betreffenden Grösse im Punkte M genommen wird. Weiter bezeichnen wir: $\tau_{m\bar{k}} = T_{m\bar{k}}(z, \bar{a})$; $\sigma_{m\bar{k}} = S_{m\bar{k}}(w, \bar{b})$.

Dann erhalten wir die folgenden Sätze:

Satz 1. *Jede lokalisometrische Abbildung eines Bereiches $\mathfrak{B}$ bezüglich des Punktes M auf einen Bereich $\mathfrak{B}^*$ bezüglich des Punktes P kann in der Form*

$$u^k = \alpha^k_s v^s \tag{5}$$

dargestellt werden. Hier sind α^k_s passend gewählte Konstanten. Zu diesem Satze kommt man durch die Integration der Gleichungen (3). Er stellt eine Verallgemeinerung eines Satzes von Welke ([4]) auf den Fall der lokalisometrischen Abbildungen dar.

Satz 2. *Damit eine lokalisometrische Abbildung des Bereiches $\mathfrak{B}$ bezüglich des Punktes M auf den Bereich $\mathfrak{B}^*$ bezüglich des Punktes P existiere, ist es notwendig und hinreichend, dass für passend gewählte Konstanten γ^k_l*

$$A^{l\bar{q}}_{k\bar{r}} \gamma^k_l \overline{\gamma^r_q} = 1 \tag{6}$$

ist. Hier bedeutet

$$A^{l\bar{q}}_{k\bar{r}} = \sigma^{n\bar{q}} S^{(P)}_{nm} \overline{\sigma^{m\bar{r}}} \tau_{p\bar{r}} T^{p\bar{s}}_{(M)} \overline{\tau_{s\bar{k}}}. \tag{7}$$

Daraus erhält man leicht auch eine notwendige und hinreichende Bedingung für die Existenz der lokalisometrischen Abbildungen des Bereiches $\mathfrak{B}$ bezüglich des Punktes M auf den Bereich $\mathfrak{B}^*$. Diese Bedingung besteht in der Möglichkeit die Gleichung (6) durch eine passende Wahl der Grössen γ^k_l, b^k zu befriedigen.

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MATHÉMATIQUES

SUR UN THÉORÈME DE L'ANALYSE FONCTIONNELLE

Par S. SOBOLEFF, membre correspondant de l'Académie

Dans le présent article nous donnons la démonstration d'un théorème de l'analyse fonctionnelle, applicable à la théorie des équations aux dérivées partielles. Dans la note suivante nous montrerons comment le résultat obtenu peut être appliqué par exemple à la théorie des équations quasi-linéaires hyperboliques à n variables indépendantes.

Considérons dans un espace à n dimensions un domaine D dont chaque point M est accessible au moyen d'un secteur sphérique V_M de forme et de grandeur constantes qui se trouve à l'intérieur de D (D peut être infini). Soit $\varphi(x_1, x_2, \dots x_n)$ une fonction des variables $x_1, \dots x_n$ sommable dans D. Soit $\psi(x_1, \dots x_n)$ une fonction dont les dérivées partielles jusqu'à l'ordre α sont continues dans D et s'annullent en dehors d'un domaine D' intérieur à D. S'il existe une fonction $\omega_{\alpha_1,\dots\alpha_n}(x_1, x_2, \dots x_n)$ sommable dans D et telle que l'identité suivante a lieu:

$$\overbrace{\int\dots\int}^{n}_{D}\left(\psi\omega_{\alpha_1,\dots\alpha_n}+(-1)^{\alpha}\varphi\frac{\partial^{\alpha}\psi}{\partial x_1^{\alpha_1}\dots\partial x_n^{\alpha_n}}\right)dx_1\dots dx_n=0, \tag{1}$$

quelle que soit la fonction ψ précédemment définie nous disons que la fonction φ admet la dérivée:

$$\frac{\partial^{\alpha}\varphi}{\partial x_1^{\alpha_1}\dots\partial x_n^{\alpha_n}}=\omega_{\alpha_1,\dots\alpha_n}{}^{*}. \tag{2}$$

Le résultat principal de cet article est le théorème:

Théorème fondamental. *Si la fonction φ admet dans D toutes les dérivées d'un certain ordre l et si elles sont toutes à p sommables où $p\leqslant\frac{n}{l}$, la fonction $|\varphi|$ est elle-même à q sommable*:

$$\frac{1}{q}=\frac{1}{p}-\frac{l}{n}. \tag{3}$$

* Si φ admet une dérivée continue au sens classique, notre définition coïncide avec la définition classique. Mais le fait que la dérivée existe presque partout est indépendant de l'existence de la dérivée dans le sens indiqué. [Exemples triviaux: 1) $\varphi=f_1(x_1)+f_2(x_2)$. Suivant la définition dans le texte $\frac{\partial^2\varphi}{\partial x_1\partial x_2}=0$ tandis que dans le sens classique la dérivée peut ne pas exister; 2) $\varphi=F(x_1)$ où $F(x_1)$ n'est pas absolument continue. Dans ce cas la dérivée dans le sens du texte n'existe pas.]

Dans ce cas l'intégrale:

$$\overbrace{\int\cdots\int}^{n}_{D} |\varphi|^q \, dx_1 \ldots dx_n \tag{4}$$

peut être évaluée au moyen d'intégrales de $|\varphi|^r$, *où* $1 \leqslant r \leqslant q$, *et l'on a:*

$$\left[\overbrace{\int\cdots\int}^{n}_{D} |\varphi|^q \, dx_1 \ldots dx_n\right]^{\frac{1}{q}} \leqslant L_1 \left[\overbrace{\int\cdots\int}^{n}_{D} |\varphi|^r \, dx_1 \ldots dx_n\right]^{\frac{1}{r}} +$$

$$+ L_2 \left[\overbrace{\int\cdots\int}^{n}_{D} \sum_{a_1,\ldots a_n} \left|\frac{\partial^l \varphi}{\partial x_1^{a_1} \ldots \partial x_n^{a_n}}\right|^p dx_1 \ldots dx_n\right]^{\frac{1}{p}}. \tag{5}$$

Les constantes L_1 et L_2 *ne dépendent pas du choix de la fonction* φ *mais seulement de* p, q, r et n.

Le cas où $p > \frac{n}{l}$ a été examiné pour $p = 2$ par l'auteur (1), (2) et pour p arbitraire par V. Kondrachov (3). Il a été démontré que dans ce cas la fonction φ est une fonction bornée et uniformément continue.

Nous démontrerons le théorème en question d'abord pour les fonctions φ ayant des dérivées continues dans le sens classique. Après avoir établi l'inégalité (5) pour les fonctions de ce genre, on peut se servir de la méthode des fonctions moyennes (4). Pour chaque fonction sommable φ on construit la suite:

$$\varphi_m = C_1 m^n \overbrace{\int\cdots\int}^{n}_{r \leqslant \frac{1}{m}} e^{\frac{m^2 r^2}{m^2 r^2 - 1}} \varphi(x_1', \ldots x_n') \, dx_1' \ldots dx_n', \tag{6}$$

$$r = \sqrt{\sum (x_i - x_i')^2}.$$

Il est établi que cette suite converge vers φ presque partout et d'ailleurs dans tous les espaces L_p auxquels la fonction φ appartient elle-même. φ_m sera nommée la fonction moyenne de φ. Remarquons que la dérivée de la fonction moyenne est la moyenne de la dérivée, si cette dernière est prise dans le sens précédemment indiqué. Le passage à la limite dans la formule (5) nous donne un cas général du théorème en question. L'élément essentiel pour la démonstration est le théorème suivant:

Théorème II (théorème généralisé de F. Riesz). *Soit* $g(x_1, \ldots x_n)$ *une fonction des variables* $x_1, \ldots x_n$ *à* p *sommable pour un certain* $p > 1$ *et* $h(y_1, \ldots y_n)$ *— une fonction à* q *sommable pour un certain* $q > 1$. *Soit* $\frac{1}{p} + \frac{1}{q} > 1$. *Alors l'inégalité suivante est vraie:*

$$\int\cdots\int\int\cdots\int \frac{g(x_1, \ldots x_n)\, y(y_1 \ldots y_n)}{r^\lambda} \, dx_1 \ldots dx_n \, dy_1 \ldots dy_n \leqslant$$

$$\leqslant K \left[\int\cdots\int |g|^p \, dx_1 \ldots dx_n\right]^{\frac{1}{p}} \left[\int\cdots\int |h|^q \, dy_1 \ldots dy_n\right]^{\frac{1}{q}}, \tag{7}$$

où

$$\lambda = n\left(2 - \frac{1}{p} - \frac{1}{q}\right), \tag{8}$$

et K *ne dépend pas du choix de* g *et* h (5).

La démonstration de ce théorème est analogue à la démonstration de celui de F. Riesz. On établit d'abord le lemme:

Lemme I. *Soit* $g(x_1, \dots x_n)$ *une certaine fonction mesurable du point* $x_1, \dots x_n$. *Désignons par* $g^*(x_1, \dots x_n)$ *une fonction dépendant seulement de* $r = \sqrt{\sum_{i=1}^{n} x_i^2}$ *non croissante et telle que* $m(g > A) = m(g^* > A)$ *quel que soit* A. *Alors l'inégalité suivante a lieu:*

$$I = \int \dots \int \int \dots \int g(x_1, \dots x_n)\, h(y_1, y_2, \dots y_n) \times$$

$$\times f(x_1 - y_1, \dots x_n - y_n)\, dx_1, \dots dx_n\, dy_1, \dots dy_n \leqslant$$

$$\leqslant \int \dots \int \int \dots \int g^*(x_1, \dots x_n)\, h^*(y_1, \dots y_n) \times$$

$$\times f^*(x_1 - y_1, \dots x_n - y_n)\, dx_1 \dots dx_n\, dy_1 \dots dy_n = I^*. \tag{9}$$

Ce lemme ainsi que le lemme correspondant de Riesz peut être réduit au cas où toutes les trois fonctions g, h et f ne prennent que les deux valeurs 0 et 1.

Pour $n = 1$ cette inégalité a été établie par F. Riesz. Le passage au cas où $n > 1$ peut être effectué au moyen d'opérations de symétrisation de Steiner et de Schwarz. Supposons que l'équation (9) est vraie pour $(n-1)$ variables indépendantes; nous pouvons alors décomposer l'intégration $2n$-uple en effectuant l'intégration extérieure par rapport à une seule paire de variables x_i, y_i. Transformons maintenant l'intégrale intérieure en remplaçant les ensembles où $f = 1$, $g = 1$ et $h = 1$ par des sphères de la même mesure ce qui ne diminuera pas l'intégrale en question. En complétant ce procédé par l'opération de symétrisation [6] nous arriverons à démontrer le lemme d'abord pour un cas particulier et puis pour le cas général.

Enonçons un autre lemme.

Lemme II. *Soient* $x_1^{(1)}, \dots x_n^{(1)}$, $x_1^{(2)}, \dots x_n^{(2)}$ *deux points quelconques de notre espace. Soient*

$$r_1 = \sqrt{\sum (x_i - x_i^{(1)})^2},\quad r_2 = \sqrt{\sum (x_i - x_i^{(2)})^2},\quad r = \sqrt{\sum (x_i^{(1)} - x_i^{(2)})^2}.$$

Soient encore $g(r_1)$ *et* $h(r_2)$ *deux fonctions positives non croissantes de leurs arguments. Alors l'inégalité suivante a lieu:*

$$\int \dots \int_{\substack{r_1 \leqslant r \\ r_2 \leqslant r}} g(r_1)\, h(r_2)\, dx_1 \dots dx_n \leqslant$$

$$\leqslant K r^{-n} \int \dots \int_{\substack{r_1 \leqslant r \\ r_2 \leqslant r}} g(r_1)\, dx_1 \dots dx_n \int \dots \int_{\substack{r_1 \leqslant r \\ r_2 \leqslant r}} h(r_2)\, dx_1 \dots dx_n, \tag{10}$$

où K *est une constante.*

L'inégalité (10) est une généralisation de l'inégalité classique de Tchebychev:

$$\int_a^b g(x)\, h(x)\, dx \leqslant \frac{1}{b-a} \int_a^b g(x)\, dx \int_a^b h(x)\, dx, \tag{11}$$

pour les fonctions dont l'une est non croissante et l'autre non décroissante. Pour démontrer le lemme II on se sert d'un système spécial de

coordonnées et on applique l'inégalité (11) en évaluant séparément la partie de l'intégrale (10), où $r_1 \geqslant r_2$, et celle, où $r_2 \geqslant r_1$. Il faut se servir aussi de l'inégalité de Hardy (7):

$$\int_0^\infty x^{-\alpha p}\Big(\int_0^x y^{1-\alpha} f(y)\,dy\Big)^p dx \leqslant \Big(\frac{p}{\alpha p-1}\Big)^p \int_0^\infty f(y)^p\,dy. \tag{12}$$

Pour démontrer le théorème II quand $g^*(r_1)$ et $h^*(r_2)$ sont non croissantes nous divisons le domaine d'intégration en trois parties: $D_1(r > r_1, r > r_2)$, $D_2(r_1 > r, r_1 > r_2)$ et $D_3(r_2 > r, r_2 > r_1)$. En effectuant dans D_1 l'intégration extérieure par rapport à $z_i = x_i - y_i$, dans D_2 par rapport à $x_1, \dots x_n$ et dans D_3 par rapport à $y_1, \dots y_n$, nous pouvons appliquer chaque fois le lemme II pour évaluer l'intégrale intérieure. De cette façon on obtient:

$$\begin{aligned} I^* \leqslant K_1 \int_0^\infty r^{-\lambda-1}\Big[\int_0^r g^*(r_1) r_1^{n-1} dr_1\Big]\Big[\int_0^r h^*(r_2) r_2^{n-1} dr_2\Big] dr + \\ + K_2 \int_0^\infty g^*(r_1) r_1^{n-\lambda-1}\Big[\int_0^{r_1} h^*(r_2) r_2^{n-1} dr_2\Big] dr_1 + \\ + K_2 \int_0^\infty h^*(r_2) r_2^{n-\lambda-1}\Big[\int_0^{r_2} g^*(r_1) r_1^{n-1} dr_1\Big] dr_2. \end{aligned} \tag{13}$$

Le reste coïncide mutatis mutandis avec les raisonnements de Riesz. On déduit du théorème II d'une façon connue le théorème suivant:

Théorème III. *Soit $h(y_1, \dots y_n)$ une fonction à p sommable, où $p > 1$. L'intégrale:*

$$f(x_1, \dots x_n) = \int_\omega \dots \int \frac{h(y_1, \dots y_n)}{r^\lambda}\, dy_1 \dots dy_n, \tag{14}$$

où

$$\lambda < \frac{n}{p'} = n\Big(1 - \frac{1}{p}\Big),$$

est une fonction à q sommable, où

$$\frac{1}{q} = \frac{1}{p} + \frac{\lambda}{n} - 1.$$

Passons à la démonstration du théorème I. La valeur de la fonction $\varphi(x_1^0, \dots x_n^0)$ (si elle possède des dérivées continues) s'exprime dans la forme:

$$\begin{aligned} \varphi(x_1^0, \dots x_n^0) = N \int_{V_M} \dots \int \Big\{ \frac{\partial^l \varphi}{\partial r^l} (-1)^l \frac{r^{l-n}}{(l-1)!} \psi\Big(\frac{r}{h}\Big) + \\ + \frac{\varphi}{r^{n-1}} \frac{\partial^l}{\partial r^l}\Big[\frac{r^{l-1}}{(l-1)!}\psi\Big(\frac{r}{h}\Big)\Big]\Big\} \chi\Big(\frac{\vartheta_1}{\alpha}\Big) dx_1 \dots dx_n, \end{aligned} \tag{15}$$

où N est une constante, h — le rayon du secteur sphérique V_M, 2α — l'angle du sommet de ce secteur, ϑ_1 — la coordonnée polaire,

$$\chi(\xi) = 0 \text{ si } \xi > 1, \quad \psi(\xi) = \begin{cases} 0 & \xi \geqslant \frac{2}{3} \\ 1 & \xi \leqslant \frac{1}{3} \end{cases}$$

χ et ψ étant infiniment dérivables. En appliquant à l'identité (15) le théorème III nous obtenons la démonstration du théorème I.

Indiquons une conséquence du theorème I qui est importante pour ses diverses applications.

Soit $F(x_1, \dots x_n, y_1, \dots y_m)$ une fonction continue de $x_1, \dots x_n$ et des paramètres $y_1, \dots y_m$. Admettons d'ailleurs que les dérivées de cette fonction jusqu'à l'ordre l par rapport aux paramètres $y_1, \dots y_m$ sont aussi continues tandis que les dérivées

$$\frac{\partial^{\alpha}}{\partial x_1^{\alpha_1} \dots \partial x_n^{\alpha_n}} \left(\frac{\partial^{\beta} F}{\partial y_1^{\beta_1} \dots \partial y_m^{\beta_m}} \right)$$

sont à p sommables où $p \geqslant \frac{n}{l}$. Nous disons alors que la fonction F possède la propriété T). Alors le théorème suivant est vrai:

Théorème IV. *Si nous substituons dans une fonction*

$$F(x_1, \dots x_n, y_1, \dots y_m)$$

qui possède la propriété T) au lieu des y_i des fonctions

$$y_i = \psi_i(x_1, \dots x_n, z_1, \dots z_k)$$

possédant la propriété T), le résultat

$$\overline{\Phi}(x_1, \dots x_n, z_1, \dots z_k) = F(x_1, \dots x_n, y_1, \dots y_m)$$

sera une fonction possédant encore la propriété T).

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MATHEMATICAL PHYSICS

ON FLUCTUATIONS IN THE NEIGHBOURHOOD OF PERIODIC MOTION OF AN AUTO-OSCILLATING SYSTEM

By I. BERSTEIN

(Communicated by L. I. Mandelstam, Member of the Academy, 26.IV.1938)

In this note an attempt is made to investigate approximately the problem of fluctuations in the neighbourhood of periodic motion of auto-oscillating systems with one degree of freedom closely approaching linear conservative systems.

The solution of the problem is obtained using the Einstein-Fokker equation. In this equation the coefficients characterizing the dynamical process are determined by van der Pol's method ([1], [2]), well known from the theory of non-linear oscillations, while the coefficients describing the statistical process are expressed through the quantities known from the theory of fluctuations in electric circuits.

The contents of separate paragraphs are as follows:

§ 1. Derivation of the fundamental Einstein-Fokker equation.

§ 2. Solution of this equation for the so-called «isotropic» case and computation for this case of the amplitude and phase fluctuations and the diffuseness of the spectrum.

§ 3. Solution of the fundamental equation and computation of the spectrum under more general assumptions.

§ 4. Application of the results to a valve scheme.

It is intended to give elsewhere the theory of an experiment for verification of the results obtained in this note.

§ 1. Let us assume that the behaviour of the system in question is described by the equations:

$$\begin{aligned} \frac{dx}{d\tau} &= y + \mu F(x, y) + f_1(\tau), \\ \frac{dy}{d\tau} &= -x + \mu G(x, y) + f_2(\tau), \end{aligned} \tag{A}$$

where μ is a sufficiently small parameter defining the degree of proximity of our dynamical system to the linear conservative system, and $f_1(\tau)$, $f_2(\tau)$ are functions representing the so-called «random» actions on the system. Introducing the polar co-ordinates ($x = R\cos\vartheta$, $y = R\sin\vartheta$) and taking, after van der Pol, mean values of the dynamical terms with respect to ϑ, we have:

$$\begin{aligned} \frac{dR}{d\tau} &= \mu\Phi(R) + f_1(\tau)\cos\vartheta + f_2(\tau)\sin\vartheta, \\ \frac{d\vartheta}{d\tau} &= -1 + \mu\Psi(R) - \frac{f_1(\tau)}{R}\sin\vartheta + \frac{f_2(\tau)}{R}\cos\vartheta, \end{aligned}$$

where

$$\Phi(R)=\frac{1}{2\pi}\int_0^{2\pi}[F(R\cos\vartheta,\ R\sin\vartheta)\cos\vartheta+G(R\cos\vartheta,\ R\sin\vartheta)\sin\vartheta]\,d\vartheta$$

$$\Psi(R)=\frac{1}{2\pi R}\int_0^{2\pi}[-F(R\cos\vartheta,R\sin\vartheta)\sin\vartheta+G(R\cos\vartheta,R\sin\vartheta)\cos\vartheta]\,d\vartheta.$$

Let $R=R_0$ $(R_0>0)$ be the root of the equation $\Phi(R)=0$ and let $\Phi'(R_0)\neq 0$. For dynamical equations obtained by van der Pol's method, the circumference $R=R_0$ will be then a stable limiting cycle to which corresponds the sinusoidal motion $x=R_0\cos\omega\tau$, where $\omega=1-\mu\Psi(R_0)$.

To investigate accidental deviations of the motion from the sinusoidal motion, we put $R=R_0+z$ and pass to the equations for z and ϑ, neglecting terms containing higher powers of z. In this way we obtain:

$$\begin{aligned}\frac{dz}{d\tau}&=-p_1z+f_1(\tau)\cos\vartheta+f_2(\tau)\sin\vartheta,\\ \frac{d\vartheta}{d\tau}&=-\omega+p_2z-\frac{f_1(\tau)}{R_0}\sin\vartheta+\frac{f_2(\tau)}{R_0}\cos\vartheta,\end{aligned}\qquad\text{(B)}$$

where $p_1=-\mu\Phi'(R_0);\qquad p_2=\mu\Psi'(R_0).$

We shall assume that the «random» functions $f_1(\tau)$ and $f_2(\tau)$ are such that there exist limits:

$$b_1=\lim_{\Delta\tau\to 0}\frac{\overline{\left[\int_\tau^{\tau+\Delta\tau}f_1(\tau)\,d\tau\right]^2}}{\Delta\tau};\qquad b_2=\lim_{\Delta\tau\to 0}\frac{\overline{\left[\int_\tau^{\tau+\Delta\tau}f_2(\tau)\,d\tau\right]^2}}{\Delta\tau};$$

$$b_3=\lim_{\Delta\tau\to 0}\frac{\overline{\left[\int_\tau^{\tau+\Delta\tau}f_1(\tau)\,d\tau\int_\tau^{\tau+\Delta\tau}f_2(\tau)\,d\tau\right]}}{\Delta\tau}.$$

We shall further assume that $b_3=0$ and that b_1, b_2 do not depend on R, ϑ. Then the Einstein-Fokker equation will have the form:

$$\begin{aligned}\frac{\partial w}{\partial\tau}-\frac{\partial}{\partial z}(p_1zw)-\omega\frac{\partial w}{\partial\vartheta}+\frac{\partial}{\partial\vartheta}(p_2zw)=\frac{D}{2}\Big\{R_0^2\frac{\partial^2}{\partial z^2}[(1-q\cos 2\vartheta)w]+\\ +2R_0\frac{\partial^2}{\partial z\partial\vartheta}[q\sin 2\vartheta w]+\frac{\partial^2}{\partial\vartheta^2}[(1+q\cos 2\vartheta)w]\Big\},\end{aligned}\qquad\text{(C)}$$

where $D=\frac{b_1+b_2}{2R_0^2};\quad q=\frac{b_2-b_1}{b_1+b_2}.$

This equation, together with the relations $x=(R_0+z)\cos\vartheta$, $y=(R_0+z)\sin\vartheta$ is the ideal mathematical model which approximately describes, under the assumptions made, the behaviour of the auto-oscillating system in question in the neighbourhood of the stable periodic state. It is obvious that the problem of the diffuseness of the spectrum can be solved with the aid of this ideal model only near the principal frequency of the dynamical system.

§ 2. Let us consider the case of «isotropic» fluctuations, when $b_2=b_1$ and hence $q=0$. In this case (C) becomes an equation with constant coefficients. The solution of this equation we are interested in has the form:

$$w(z_0, \vartheta_0;\ z, \vartheta;\ \tau-\tau_0) =$$

$$= \frac{1}{2\pi\sqrt{2\pi\alpha_{11}}}\, e^{-\frac{(z-\alpha_1)^2}{2\alpha_{11}}} \left\{1+2\sum_{n=1}^{\infty} e^{-\frac{n^2\delta}{2\alpha_{11}}} \cos\, n\left[\vartheta-\alpha_2-\frac{\alpha_{12}}{\alpha_{11}}(z-\alpha_1)\right]\right\}, \qquad \text{(D)}$$

where

$$\alpha_1 = z_0 e^{-p_1(\tau-\tau_0)};\ \alpha_2 = \vartheta_0-\omega\,(\tau-\tau_0)+\frac{p_2}{p_1}\, z_0\left[1-e^{-p_1(\tau-\tau_0)}\right],$$

$$\alpha_{11} = \frac{DR_0^2}{2p_1}\left[1-e^{-2p_1(\tau-\tau_0)}\right],$$

$$\alpha_{22} = \left[D+\frac{Dp_2^2R_0^2}{p_1^2}\right](\tau-\tau_0)+\frac{DR_0^2}{2}\,\frac{p_2^2}{p_1^3}\left[4e^{-p_1(\tau-\tau_0)}-e^{-2p_1(\tau-\tau_0)}-3\right],$$

$$\alpha_{12} = \frac{DR_0^2}{2}\,\frac{p_2}{p_1^2}\left[1-2e^{-p_1(\tau-\tau_0)}+e^{-2p_1(\tau-\tau_0)}\right];\qquad \delta = \alpha_{11}\alpha_{22}-\alpha_{12}^2.$$

For $\tau \to +\infty$ we obtain stationary solution:

$$w_0(z, \vartheta) = \frac{1}{2\pi}\sqrt{\frac{p_1}{\pi DR_0^2}}\, e^{-\frac{p_1 z^2}{DR_0^2}}.$$

These formulae enable us to compute the amplitude and phase fluctuations and the diffuseness of the spectrum. We shall carry out the calculations for $p_2 = 0$, since for $p_2 \neq 0$ they become very involved. It may be mentioned here that the condition $p_2 = 0$ is realized in most of the ordinary schemes.

For the fluctuations of amplitude we have (for $\tau \to \infty$)

$$\overline{z^2} = \frac{DR_0^2}{2p_1}. \qquad \text{(E)}$$

This formula shows that the amplitude fluctuations increase rapidly when the system approaches (with the change of its parameter) the bifurcational values corresponding to $p_1 = 0$*.

In finding the solution (D) it was assumed that ϑ varies from 0 to 2π. The assumption that ϑ varies from $-\infty$ to $+\infty$ leads to a somewhat more complicated solution, since in this case there is no stationary density of probability different from zero. It may be noticed that by reckoning the angles in this way we obtain for the phase fluctuations the usual diffusion law:

$$\overline{(\vartheta+\omega\tau)^2} = D\tau. \qquad \text{(F)}$$

Following Léontowitsch [3] we can use the Einstein-Fokker equation to find the diffuseness of the spectrum. Let T be some time interval which we shall increase to infinity. Representing the motion in question by the Fourier series

$$x = (R_0+z)\cos\vartheta = \sum_{n=1}^{\infty}[a_n \cos \nu_n\tau + b_n \sin \nu_n\tau], \qquad \text{(G)}$$

where

$$\nu_n = \frac{2\pi}{T}\, n,$$

we obtain for the mean values of the products of Fourier coefficients

* It must be remembered that for very small p_1 the equation (E) ceases to be valid, since in forming the Einstein-Fokker equation we cannot then neglect the nonlinearity of the dynamical equations.

$$\overline{a_n a_m} = \frac{4}{T^2}\int_0^T\int_0^T \overline{x(\tau_0)\,x(\tau)}\cdot \cos\nu_n\tau_0\,\cos\nu_m\tau\,d\tau_0\,d\tau;$$

there are similars expression for $\overline{b_n b_m}$, $\overline{a_n b_m}$ and so on. Here

$$\overline{x(\tau_0)\,x(\tau)} = \int_{-\infty}^{+\infty} dz_0 \int_0^{2\pi} d\vartheta_0 x_0 w_0\,(z_0, \vartheta_0)\overline{x(u)}\,, \qquad \text{(H)}$$

$$x_0 = (R_0 + z_0)\cos\vartheta_0; \qquad u = \tau - \tau_0$$

and

$$\overline{x(u)} = \int_{-\infty}^{+\infty} dz \int_0^{2\pi} d\vartheta x w\,(z_0, \vartheta_0;\ z, \vartheta;\ u).$$

After some calculations we get:

$$\overline{x(\tau_0)\,x(\tau)} = \frac{R_0^2}{2}\,e^{-\frac{a_{12}}{2}}\left(1 + \frac{D}{2p_1}\,e^{-p_1 u}\right)\cos\omega u.$$

Finally, for sufficiently large T, we have with any degree of accuracy

$$\overline{a_n^2} = \overline{b_n^2} = \frac{DR_0^2}{2T}\left\{\frac{1}{\frac{D^2}{4} + (\nu_n - \omega)^2} + \frac{1}{\frac{D^2}{4} + (\nu_n + \omega)^2} + \right.$$

$$\left. + \frac{D + p_1}{p_1}\left[\frac{1}{\left(\frac{D}{2} + p_1\right)^2 + (\nu_n - \omega)^2} + \frac{1}{\left(\frac{D}{2} + p_1\right)^2 + (\nu_n + \omega)^2}\right]\right\},$$

and, similarly, with the same degree of accuracy

$$\overline{a_n} = \overline{b_n} = \overline{a_n b_n} = 0 \quad \text{and} \quad \overline{a_n a_m} = \overline{b_n b_m} = \overline{a_n b_m} = 0 \quad (n \neq m).$$

Bearing in mind that the number of terms in Fourier series with frequencies lying within a sufficiently narrow range $\Delta\nu$ is $\Delta n = \frac{T}{2\pi}\Delta\nu$, we shall pass from the mean values of the squares of Fourier coefficients to the mean density of the spectrum defined by

$$\overline{C^2(\nu_n)}\,\Delta\nu = \left[\overline{a_n^2} + \overline{b_n^2}\right]\Delta n.$$

Noticing, further, that in the cases of practical interest we always have

$$\omega \gg p_1 \gg D\,^*, \qquad \text{(K)}$$

we find that the picture of the spectrum in the immediate vicinity of the principal frequency of the dynamical system is given by

$$\overline{C^2(\nu)} = \frac{DR_0^2}{2\pi}\cdot\frac{1}{\frac{D^2}{4} + (\nu - \omega)^2}\,. \qquad \text{(L)}$$

Let us introduce an arbitrary «width of the spectrum»

$$\delta\nu = \frac{\int_0^\infty \overline{C^2(\nu)}\,d\nu}{\left[\overline{C^2(\nu)}\right]_{\max}}\,.$$

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* Usually $\frac{p_1}{\omega} \approx 10^{-3}$ and $\frac{D}{\omega} \approx 10^{-10}$.

Then

$$\delta\nu \approx \frac{\pi}{2} D.$$

§ 3. The simple results reached above refer to the case $q=0$, i. e. $b_1=b_2$. In practice, however, $b_1 \neq b_2$ and q is often near 1. In the latter case we shall seek to express both the stationary probability w_0 and $\overline{x(u)}$ in the form of a power-series in q, putting, as before, $p_2=0$. To determine $\overline{x(u)}=\overline{(R_0+z)\cos\vartheta}$ we have to find $\overline{\cos\vartheta}$ and $\overline{z\cos\vartheta}$. Multiplying the equation (C) successively by $\cos\vartheta$, $\sin\vartheta$ and integrating with respect to ϑ from 0 to 2π and with respect to z from $-\infty$ to $+\infty$, we obtain two ordinary differential equations for $\overline{\cos\vartheta}$, $\overline{\sin\vartheta}$, containing $\overline{\cos 3\vartheta}$ and $\overline{\sin 3\vartheta}$. In a similar way we derive equations for $\overline{\cos 3\vartheta}$ and $\overline{\sin 3\vartheta}$, containing $\overline{\cos 5\vartheta}$ and $\overline{\sin 5\vartheta}$, and so on. From these equations we can find any number of terms in the expansion of $\overline{\cos\vartheta}$ into a power-series in q. The series for $\overline{z\cos\vartheta}$ is obtained in the same manner. Substituting the respective series for w_0 and $\overline{x(u)}$ in (H) we obtain a power-series in q for the spectrum.

Neither the convergence of the series for $\overline{x(u)}$ and w nor the convergence of the series for the spectrum have been proved. However, the calculations indicate that the terms with q and q^2 in the spectrum series are, under the condition (K), vanishingly small in comparison with the principal terms given in (L)*.

§ 4. As an example of the application of the above theory, consider the scheme of a dynatron generator. Using the commonly adopted notation we can write the equations of the idealized scheme in the form:

$$L\frac{di}{dt}+ri-v=\varphi_1(t); \qquad C\frac{dv}{dt}+i=i_a=F(v)+\varphi_2(t).$$

Here $\varphi_1(t)$ denotes the random electromotive force causing the so-called thermal effect, and $\varphi_2(t)$ is the random current corresponding to the shot effect. It is known that

$$\lim_{\Delta t\to 0}\frac{\overline{\left[\int_t^{t+\Delta t}\varphi_1(t)\,dt\right]^2}}{\Delta t}=2rkT,$$

where r is the ohmic resistance of the circuit, k is Boltzmann's constant and T—the absolute temperature. We shall denote

$$\lim_{\Delta t\to 0}\frac{\overline{\left[\int_t^{t+\Delta t}\varphi_2(t)\,dt\right]^2}}{\Delta t}=Q.$$

If the space charge is not too great, this quantity is of the same order of magnitude as in the saturated diode ([4], [5]), i. e.

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* The terms with q give a correction of the order $\frac{D}{\omega}$ and those with q^2—of the order $\left(\frac{D}{\omega}\right)^2$. It thus follows that if the formula (L) is sufficiently accurate also for $q\neq 0$, the diffuseness of the spectrum can de determined, under the condition (K), by taking mean values in ϑ of the statistical coefficients in the Einstein-Fokker equation, just as means of the dynamical coefficients are taken in van der Pol's method.

$$Q \approx e I_0,$$

where e is the charge of the electron and I_0 the mean anode current.

Putting $\frac{1}{\sqrt{LC}} = \omega$, $i\sqrt{\frac{L}{C}} = x$, $v = y$ we can rewrite the equations of the sheme in the following form:

$$\frac{dx}{dt} = \omega y - \frac{r}{L} x + \omega \varphi_1(t); \quad \frac{dy}{dt} = -\omega x + \frac{1}{C} F(y) + \frac{1}{C} \varphi_2(t),$$

whence

$$b_1 = \omega^2 2rkT; \quad b_2 = \frac{Q}{C^2}; \quad b_{12} = 0; \quad D = \frac{\omega^2}{2R_0^2}\left[2rkT + \frac{L}{C} Q\right].$$

We shall determine now the order of magnitude of the diffuseness of the spectrum. Putting $\omega = 2\pi \cdot 3 \cdot 10^6$ sec.$^{-1}$, $R_0 = 15$ volts, $r = 30\,\Omega$, $T = 300°$, $\sqrt{\frac{L}{C}} = 10^3\,\Omega$, $I_0 = 10^{-2}$ ampere, we have for the width of the spectrum $\delta\omega$ introduced in the preceding paragraph

$$\frac{\delta\omega}{\omega} \approx \frac{D}{\omega} \approx \frac{\omega}{2R_0^2} \frac{LQ}{C} \approx 10^{-10}\,*.$$

To evaluate the amplitude fluctuations, we represent the characteristic of the dynatron as

$$F(v) = I_0 + \alpha v - \gamma v^3 \qquad (\alpha > 0;\ \gamma > 0),$$

whence $\mu\Phi(R) = \frac{\omega^2 R}{2}\left(\alpha L - rC - \frac{3}{4}\gamma L R^2\right)$; $\mu\Psi(R) \equiv 0$,

and $R_0^2 = \frac{4(\alpha L - rC)}{3\gamma L}$; $p_1 = \frac{3}{4}\gamma\omega^2 L R_0^2$; $p_2 = 0$.

Putting $\gamma = 10^{-8}$, we have

$$p_1 \approx 5 \cdot 10^4; \quad \frac{p_1}{\omega} \approx 2 \cdot 10^{-3}; \quad \frac{D}{p_1} \approx 5 \cdot 10^{-8}.$$

For the mean square of the amplitude fluctuations we obtain:

$$\frac{\sqrt{\overline{z^2}}}{R_0} = \sqrt{\frac{D}{2p_1}} \approx 10^{-4}.$$

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* For a valve generator with the oscillating circuit connected to the anode, the diffuseness of the spectrum is approximately the same. When the oscillatory circuit is in the grid, the diffuseness for an idealized scheme is 10^2 to 10^3 times less.

It will be noticed that the values found here for the diffuseness of the spectrum are probably smaller than the actual ones, since we have not taken into account the effect of the non-stationary cathode radiation (Flickereffekt), battery fluctuations, etc.

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PHYSICS

DIRECT OBSERVATION OF RAYLEIGH WAVES IN CASE OF TOTAL REFLEXION

By S. I. KRETSCHMER and S. N. RSCHEVKIN

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As had been demonstrated by Rayleigh (1), in case of total reflexion of a sound wave on the boundary of two mediums, partial penetration of the sound into the second medium and formation in the latter of waves of a specific kind take place.

If one assumes that the sound falls from medium I onto the boundary between medium I and medium II (sound velocity c_2 in the latter being more than velocity c_1 in medium I) at an angle of incidence θ_1, then the equation of the wave in medium II will obtain the following form (provided the angle of incidence is larger than the limit angle of total reflexion):

$$\Phi_2 = A_2 e^{-\alpha x} e^{j(\omega t + by + \varepsilon)}. \qquad (1)$$

It should be assumed that axis x is normal, while axis y is parallel to the plane of separation between two mediums, and lies in the plane of incidence.

In equation (1) following notations are adopted:

Wave amplitude in the second medium

$$A_2 = \frac{2}{\sqrt{\frac{\rho_2^2}{\rho_1^2} + \frac{\alpha^2}{a_1^2}}}; \qquad (2)$$

ρ_1 and ρ_2, respectively, densities of mediums I and II; c_1 and c_2, velocities in mediums I and II; $a_1 = k_1 \cos\theta_1$; $b = k_1 \sin\theta_1$; $\left(k_1 = \frac{\omega}{c_1};\ k_2 = \frac{\omega}{c_2}\right)$.

Damping coefficient in the direction of x axis:

$$\alpha = \frac{2\pi}{\lambda_1}\sqrt{\sin^2\theta_1 - \frac{c_1^2}{c_2^2}}. \qquad (3)$$

Thus, in case of total reflexion waves proceeding in the direction parallel to the plane of separation will be obtained in the second medium. Such waves will dampen according to the exponential law, i. e. along the wave front, their velocity being equal: $c' = \frac{\omega}{b} = \frac{c_1}{\sin\theta_1}$. It does not depend upon the properties of the second medium, and is always larger than c_1, though

smaller than c_2. When determining the components of the velocity of particles in this wave along the axes x and y, we obtain:

$$\left.\begin{aligned}\dot{\xi}_x &= -\frac{\partial \Phi_2}{\partial x} = -\frac{2\alpha}{\sqrt{\frac{\rho_2^2}{\rho_1^2}+\frac{\alpha^2}{a_1^2}}}\, e^{-\alpha x} e^{j(\omega t+by+\varepsilon)} \\ \dot{\xi}_y &= -\frac{\partial \Phi_2}{\partial y} = -j\frac{2b}{\sqrt{\frac{\rho_2^2}{\rho_1^2}+\frac{\alpha^2}{a_1^2}}}\, e^{-\alpha x} e^{j(\omega t+by+\varepsilon)}\end{aligned}\right\} \qquad (4)$$

From (4) it may be easily seen that the components $\dot{\xi}_x$ and $\dot{\xi}_y$ differ as to the phase by 90°, and that the Rayleigh waves are consequently quasi-polarized along the ellipses which lie in the plane of incidence. The degree of polarization, i. e. the ratio of amplitudes $\dot{\xi}_x$ and $\dot{\xi}_y$, is equal to

$$\frac{\dot{\xi}_x}{\dot{\xi}_y} = \frac{\sqrt{\sin\theta_1 - \frac{c_1^2}{c_2^2}}}{\sin\theta_1}, \qquad (5)$$

i. e. is depending upon the angle of incidence and the index of refraction $\frac{c_1}{c_2}$. The more the angle of incidence exceeds the limit one, the sharper the damping of Rayleigh waves becomes expressed; in case angle

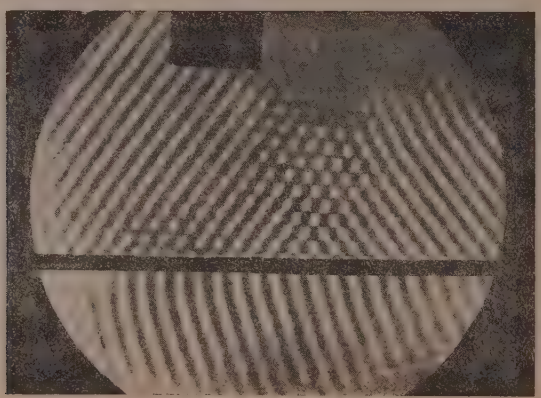

Fig. 1.

θ_1 is equal to the limit one, damping is zero. In the second medium we observe waves which have their fronts normal to the plane of separation, and suffer no weakening with deeper penetration into this medium.

In optics the phenomenon of penetration of waves into the second medium has been subject both to a detailed theoretical and experimental study (2). The presence of light waves in the second medium in case of total reflexion was proved by a number of authors from the secondary effect, while they observed the luminescence caused by those waves.

Applying the method of investigation of wave phenomena with the help of ultrasonic waves previously elaborated by us (3) (on the basis of the striae method), and utilizing stroboscopic illumination, we succeeded in making directly visible sound waves in the second medium, which had been theoretically predicted by Rayleigh.

By means of stroboscopic illumination we could observe the fronts of equal phases of running waves—the incident, the reflected and the refracted one.

Total reflexion was observed by us on the interface between vaselin oil (medium I) and 30% water solution of NaCl (medium II). Respective sound velocities were: $c_1 \approx 1500$ m/sec. and $c_2 \approx 1810$ m/sec., which gives for the limit angle of total inner reflexion the value $\approx 55°30'$.

Owing to the weakening of waves with angles of incidence exceeding the critical one along the front in the second medium, it should be expected

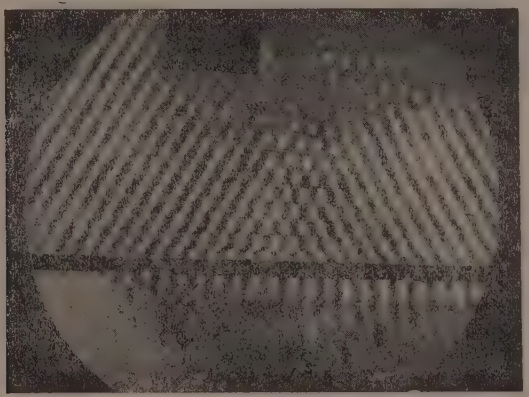

Fig. 2.

that these waves would be visible most distinctly near the plane of separation, while farther off they would gradually become vague, and, finally, fuse at a certain distance with the general background.

In the case of angles approaching the critical one, α is small and the length of the visible part of wave fronts in the second medium should obviously be larger. If the angles do considerably exceed the critical one, this length should drop rapidly, since α is materially growing.

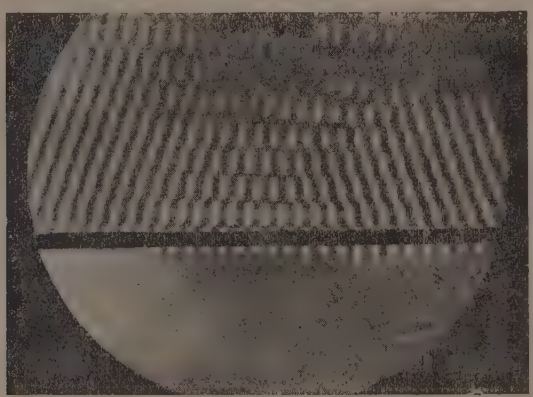

Fig. 3.

In the photos given above (Figs 1, 2, 3) these peculiarities of the waves observed in the second medium may be easily seen. All these pictures refer to the frequency 437 kHz (wave length in vaseline oil $\lambda_1 = 3.64$ mm, in NaCl solution $= 4.26$ mm).

In Fig. 1 (photo 245), with an angle of incidence $\theta_1 = 54°$, an incident and a reflected wave, and in the second medium a refracted one ($\theta_2 \approx 70°$) are visible. The boundary between vaseline oil and NaCl solution is somewhat hazy owing to the capillar raise of the NaCl solution into the

region of the oil. Its lower line exactly corresponds to the projection of the plane of separation of both mediums.

In Fig. 2 (photo 248) ($\theta_1 = 60°$) we have an example of total reflexion. In the second medium Rayleigh waves may be clearly observed which run parallel to the plane of separation, and become gradually weakened along the wave fronts as they penetrate deeper into the second medium.

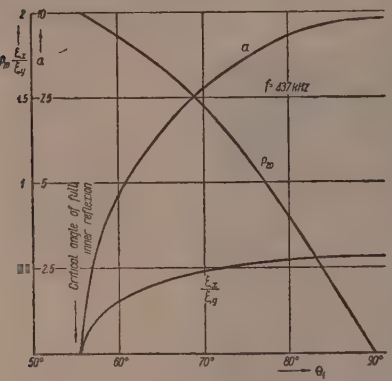

Fig. 4.

In Fig. 3 (photo 250) ($\theta_1 = 71°$) the weakening along the fronts of waves in the second medium is still more pronounced than at $\theta_1 = 60°$.

In the graph of Fig. 4 values are given which refer to the case of the liquid examined by us, viz., coefficient of weakening, ratio of the longitudinal component of the amplitude of particle velocities to the transversal one in the second medium, as well as values of the initial amplitude of pressure p_{20} in the second medium, all values depending on the angle of incidence θ_1. This graph refers to the frequency 437 kHz. It should be noted that values p_{20} and ξ_x/ξ_y do not depend upon frequency, while value α is directly proportional to the latter.

№ of photos from the labor. register	x_{cm}	θ_1	p_{20}	α	p_{min}
243	0.5	62°	1.79	5.45	0.122
247	0.5	61°	1.86	5.05	0.144
248	0.5	61°	1.86	5.05	0.144
249	0.3	67°	1.58	7.00	0.158
250	0.2	72°	1.34	8.10	0.269
251	0.15	77°	1.02	8.90	0.271

In the table values are given which express the distance x at which on a series of photos it becomes practically impossible to discern the wave structure of the field in the second medium on the background of the picture. This distance magnitude should obviously correspond (at a given optical sensitivity) to a certain minimum amplitude of pressure p_{min}. For the sake of comparison with the data observed, in the last column of the table p_{min} is computed at distances x, values of p_{20} and α corresponding to the angle of incidence θ_1. The theoretically calculated value of p_{min} proves to be of the same order as the experimental one. Since the limit of wave disappearance refuses an accurate determination, the results obtained may be regarded as satisfactory. We may thus hold that the Rayleigh waves in the second medium give us some kind of scale for a relative estimation of the intensity of sound waves. Thus, the Rayleigh waves in the II medium may serve as a kind of scale of the sound intensity.

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PHYSICS

THE PULSE CHOPPER OF THE GEIGER-MÜLLER COUNTER

By M. KOZODAEV and G. LATYSCHEV

(Communicated by A. F. Joffe, Member of the Academy, 28. IV. 1938)

Carrying out measurements with the Geiger-Müller counters it is often necessary to increase their resolving power, which is usually from $5 \cdot 10^{-3}$ to $3 \cdot 10^{-3}$ sec. with working resistances of about 10^9 ohms. This low resolving power of the counter does not permit of its use with a large number of discharges. This is very easily observed when working on coincidences which involves five or six hundred discharges per minute, since under such conditions 20—30% of the particles remain unrecorded.

The low resolving power of the counter is due to the following factors.

In using the Geiger-Müller counter it is necessary to apply high ohmic resistances (10^9—10^{10}). With lower resistances, the discharge current may exceed the permissible maximum value, which is attained when a stable discharge is established in the counter (1).

Owing to a high value of the $R \cdot C$ of the system (usually above 10^{-2} sec.), the difference of potentials between the cylinder and the filament recovers fairly slowly after the discharge, thus reducing for some time the counting power of the counter.

The choking of the discharge is due to a voltage drop across the resistance. If the overtension is increased, the strength of the discharge current may rise up to a value close to the critical one. As a result, the counter characteristics, showing the relation between the number of particles to be counted and the voltage across the counter, usually lack the horizontal portion, or the so-called plateau.

The writers have designed a system which allows to employ counters with resistances of about 10^6 ohms. Having this aim in view, the circuit shown in Fig. 1 was applied. The tube *1* is conducting when there are no discharges in the counter. The resistance R_3 has such a value that almost the whole voltage of the *B*-battery is across it, leaving on the anode of the tube a voltage of about 10 V. (This is an essential condition for the removal of such uninterrupted oscillations as may arise in the system, since we have here a multivibrator circuit). The tube *2* is fully non-conducting and its anode voltage is equal to that of the *B*-battery.

When a discharge arises in the counter, a negative pulse flows to the first tube grid, and the system is upset. The tube *2* is then conducting, since a positive pulse flows to its grid from the anode of the tube *1*, through the capacity C_2. The change in the anode voltage of the tube *2* is transmitted through the capacity C_1 as a negative pulse to the tube *1* grid. This negative

pulse is almost equal to the B-battery voltage. Since the grid of tube *1* is connected with the filament of the counter, the difference of potentials between the filament and the cylinder of the counter decreases by the value of that pulse, and the discharge ceases. After a lapse of time, the latter being determined by the values of the resistance R_2 and R_3, capacity C_2 and that of the grid of tube *2*, the system regains its initial state. The pulse shape on the grid of tube *1* was observed by means of a cathode ray oscillograph, and is shown in Fig. 2 a. In the above circuit the capacity C_1 is sufficiently large to transmit without distortion the variations of the anode potential of the tube *2* onto the tube *1* grid. The shape of the pulse is therefore primarily determined by the constants of the circuit of the tube *2* grid. The resolving power of that system, the values of the capacities and resistances of which are shown in Fig. 1, was measured by means of the oscillograph and was found equal to $\tau \approx 3 \cdot 10^{-4}$ sec. This value of the resolving power is not a limiting one for the system. In our case, the system worked about 0.1 V owing to the change in the voltage of the tube *1* grid, which with a resistance of $R_1 = 3 \cdot 10^6$ ohms corresponds to a current of $i = 3 \cdot 10^{-8}$ A across the counter. This current is about one-tenth of the maximum allowable current in the counter. This would show that the overtension is removed from the counter at the very start of the discharge, the value of the current remaining unchanged, since it does not depend on the overtension applied across the counter.

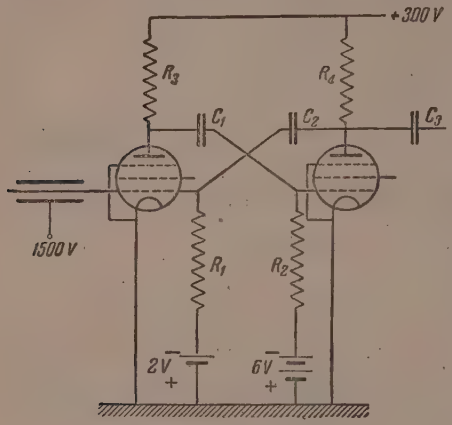

Fig. 1.

$R_1 = 3 \cdot 10^6\,\Omega$; $R_4 = 3 \cdot 10^5\,\Omega$;
$R_2 = 2 \cdot 10^6\,\Omega$; $C_1 = 10^{-11}$ F;
$R_3 = 8 \cdot 10^5\,\Omega$; $C_2 = 3 \cdot 10^{-10}$ F;
Voltage of the screen grid 40 V; Tube 6—Y—7.

This results in another important advantage of this system as compared with counters operating with usual resistances, namely, this system renders horizontal the caracteristics even of an otherwise unsatisfactory counter.

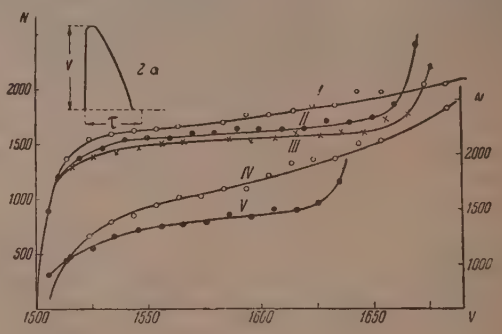

Fig. 2.

Fig. 2 illustrates this fact. Curve *IV* shows the plateau for an air-filled counter. The counter was 10 mm in diameter and 40 mm long and had in its cylinder two windows for electrons. Curve *I* shows the plateau for the same counter, when filled with argon. Argon has improved the form of the plateau. Curves *II* and *III* show the shape of the plateau of the same counter, when filled with argon and operating with resistance of 10^7 and $3 \cdot 10^6$ ohms as in the circuit shown in Fig. 1.

It may be seen therefore that a threefold variation of the resistance R_1 leaves the width of the plateau unchanged, thus the resistance R_1 may be reduced

still more. Curve V shows the shape of the plateau of an air-filled counter operated by the circuit shown in Fig. 1.

A similar circuit was independently applied by Getting [2] who points out, however, that with small counters the working range of the system was very narrow.

The above system was designed by the writers for coincidence circuit, since with resistances of about 10^9 ohms the percentage of particles left out of account is very high. The operation of the counters must be practically limited to 200—300 discharges per minute, which hinders the measurements of low intensity phenomena studied by the method of coincidences.

The percentage of particles remaining unrecorded can be calculated from the approximate equation

$$\tau \cdot (N_1 + N_2) = 100\%.$$

By means of this equation only the mean value of τ may be found, since the resolving power τ of Geiger-Müller counters working on coincidences depends on the value of the pulse. In the circuit described above, τ is a constant, being the natural period of the circuit and not depending on the processes which take place in the tube of the counter. Since the resolving power of the circuit is $\tau = 3 \cdot 10^{-4}$, it can be found from the above equation that 1% of omissions will occur in any counter loaded to about 1000 pulses per minute. We have investigated the dependence betwen the percentage of omissions and the loading of the counter, and have found that the resolving power of the system corresponds in reality to the value obtained from oscillograph data.

The above equation is only approximate. For an accurate correction of the values measured one has to apply the following equation:

$$n = \frac{n'}{(1 - \tau_1 N_1)(1 - \tau_2 N_2)},$$

where τ_1 and τ_2 are respectively the resolving powers of the first and second branches of a circuit working on double coincidences; N_1 and N_2, the loading of the counters; n', the number of coincidences counted; n, the true number of coincidences.

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PHYSICS

ON A TUBE CIRCUIT FOR THE GEIGER-MÜLLER COUNTER

By M. KOZODAEV

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In our previous paper a circuit is described which allows to obtain in the Geiger-Müller counter pulses of short duration. We have attempted to use for the same purpose the circuit shown in Fig. 1. The radio tube is in a conducting state when there is no discharge in the counter. The value of the resistance R_2 is so chosen that the full voltage supplied by the B-battery is across it. The difference of the potentials across this resistance terminals is added to the voltage of the high tension battery, connected with the cylinder of the counter. When a discharge arises in the counter, a negative pulse flows to the grid of the tube. The tube increases this pulse and as a result the difference of potentials across the terminals of the resistance R_2 decreases, and the potential difference between the cylinder and the filament decreases by the same value too. If the overtension across the counter is $\Delta\varphi_0$, and the dynamic amplifier factor of the tube is μ, then for the full removal of the overtension the pulse across the grid should be $\frac{\Delta\varphi_0}{\mu+1}$.

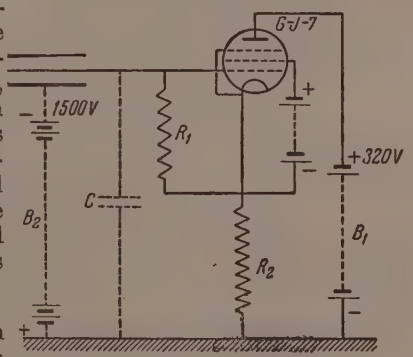

Fig. 1.

If we want to place the counter in the same working conditions as with the usual resistance, we may reduce the resistance, say, μ times, i. e. we may operate with the resistance of $R_1 \approx 5$—10 mΩ, with amplifier factor of $\mu \approx 100$—300, practically attainable. Since the counter operates with low resistance, it may be expected that, after the discharge, the increase in the counter voltage up to the initial state will be accordingly accelerated.

In fact, as shown by the oscillograph data, this process is as slow as it is with the usual resistance. That this is as it should be may be seen from the following considerations.

The filament of the counter with the connecting conductors and the grid of the tube has a certain capacity C toward the ground. When discharge takes place, the difference of potentials with this capacity decreases by the value of the overtension $\Delta\varphi_0$. When the discharge is ended, the above capacity

will be charged through the resistance R_1, up to the recovering of its initial state.

Owing to the fact that the variations in the voltages across the resistance R_1 and R_2 are connected with each other by the ratio $\mu \cdot \Delta v_1 = \Delta v_2$, the strength of the charging current flowing through the resistance R_1 is limited and cannot be higher than

$$i_m = \frac{\Delta v_1}{R_1} = \frac{\Delta v_1 + \Delta v_2}{(\mu + 1) R_1}.$$

It may be seen therefore that the process of charging the capacity C will be the same as in the usual case with the resistance $R' = (\mu + 1) R_1$.

Thus, the above system cannot reduce the duration of the pulse of the Geiger-Müller counter.

In one of the recent issues of the Physical Review Neher and Pickering [1] give a description of a similar circuit which differs from ours: namely, battery B_2 is connected with battery B_1 and the cylinder of the counter is grounded. Yet, all that was said above may also be applied to the Neher and Pickering circuit.

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CHIMIE

SUR LES DÉRIVÉS ORGANIQUES DU SCANDIUM ET DE L'YTTRIUM

Par W. M. PLETZ

(Présenté par A. N. Frumkin, de l'Académie, le 3. V. 1938)

Les dérivés organiques des élements du 3-me groupe présentent un intérêt profond par rapport à la théorie des groupements dits surradicaux ou pseudo-radicaux (1). Les composés organiques du bor, de l'aluminium, du gallium, de l'indium et du thallium montrent cette propriété curieuse (2). Conformément à la théorie de A. von Grosse les composés alkyliques typiques sont exclusivement donnés par les éléments dont tous les électrons de valence suivent des orbites ayant le même nombre de quantum. Or, les éléments qui ne correspondent pas à cette règle, c'est-à-dire à commencer par Sc jusqu'au Ni, de l'Y jusqu'au Pd, de La jusqu'au Pt et de Ac jusqu'au U (3), ne peuvent donner des composés alkyliques typiques. Or, la découverte récente de composés trialkyliques du thallium (4), du gallium (5) et de l'indium (6), et surtout la découverte du trimethylrhenium (7) faite par Druce m'ont persuadé que les dérivés organiques du scandium et de l'yttrium doivent exister et que la théorie de Grosse demande à être sérieusement corrigée.

Dans la description des expériences je passe certains détails, par exemple la préparation du scandium et de l'yttrium trichlorurés anhydre d'après un procédé que j'ai élaboré, parce que cela nous menerait trop loin et que cette description demande un article spécial.

1) Le triéthylescandiumétherate $(C_2H_5)_3Sc\,(C_2H_5)_2O$. Dans un ballon de 250 ml, pourvu d'un mélangeur à fermeture du mercure, d'un réfrigérant ascendant, d'un entonnoir à gouttelette et d'un tube amenant le nitrogène, on met 2.4 g de magnésium et à l'aide de l'entonnoir on ajoute du bromure d'éthyle (10.9 g) dissous dans 100 ml d'éther absolu. Au magnésiumbrométhyle préparé de cette facon on ajoute une suspension de 14.9 g de scandiumtrichlorure anhydre dans 50 ml d'éther absolu. Aussitôt survient une réaction signalée par une teinte jaune du mélange. La réaction est menée dans un courant de nitrogène (sec, pur et dépourvu d'oxygène) et avec réfrigération à l'eau glacée. Après avoir introduit toute la quantité de $ScCl_3$, on chauffe le mélange pendant une demi-heure au bain-marie et on chasse l'éther dans un courant de nitrogène. L'éther étant chassé, on distille le résidu dans un courant de nitrogène sur une grille d'asbeste.

L'étherate du triéthylescandium est un liquide transparent, jaunâtre, possédant une odeur désagréable qui lui est propre. Température d'ébullition 170—172° (760 mm); $d^{18°}=1.071$.

L'étherate ne s'enflamme pas à l'air, mais il fume assez fort; quand on le secoue énergiquement avec de l'air, il s'enflamme instantanément, la flamme ayant un reflet rosé particulier.

L'étherate se décompose momentanément au contact de l'eau et de l'alcool apparemment avec formation de hydroxyde $(C_2H_5)_2ScOH$. Avec de l'eau bromurée on obtient une réaction extrêmement énergique qui aboutit à l'ébullition et donne en résidu de petites aiguilles blanches insolubles dans l'eau, apparemment du bromure $(C_2H_5)_2ScBr$.

Avec du benzène, du toluène, du xylène, du ligroine et de l'éthylacetate il se mélange complètement sous tous les rapports.

Le rendement de l'étherate est de 14.5 g, c'est-à-dire 70% environ du rendement théorique.

Analyse

Calculé	Trouvé
C —58.25%	C —58.07%
H —12.13%	H —12.05%
Sc—21.84%	Sc—21.69%

2) Le triéthyleyttriumétherate $(C_2H_5)_3Y(C_2H_5)_2O$. On prépare avec 2.4 g de magnésium et 10.9 g de bromure d'éthyle de la manière ordinairement usitée de la bromure d'éthylemagnésium. On y ajoute, tout en agitant, réfrigérant et faisant passer par un courant de nitrogène, une suspension de 19.4 g d'yttriumtrichlorure anhydre dilué dans 50 ml d'éther. Il survient une réaction avec formation d'un résidu rougeâtre qui disparaît rapidement. Après une demi-heure d'ébullition au bain-marie on enlève l'éther (dans un courant de nitrogène) et on distille le reste simplement sur une grille d'asbeste.

Le triéthyleyttriumétherate est un liquide transparent, incolore, avec une odeur forte douceâtre. Température d'ébullition 222—225° (760 mm), $d^{18°} = 1.132$.

A l'air il ne s'enflamme point, mais il s'oxyde; fume assez fort et peut calciner du papier. Quand on l'allume à l'aide d'une allumette, il se consume rapidement avec une flamme d'un rouge intense. Au contact de l'eau et de l'alcool il se décompose instantanément en formant de l'hydroxyde, apparemment $(C_2H_5)_2YOH$. Avec du benzène, du toluène, du xylène il se mélange sous tous les rapports.

Rendement 20.1 g, environ 75% du rendement théorique.

Analyse

Calculé	Trouvé
C —44.00%	C —43.82%
H—10.00%	H— 9.87%
Y—35.60%	Y—35.41%

On poursuit les recherches dans le domaine de la synthèse des $(C_2H_5)_3Sc$ et des $(C_2H_5)_3Y$ libres.

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CHEMISTRY

SYNTHESIS OF HYDROBORACITE

By A. V. NIKOLAIEV and N. M. SELIVANOVA

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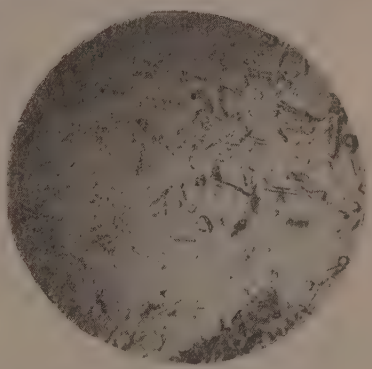
Prior to the discovery of the Inder deposit hydroboracite was classed under the head of rare boron minerals. Only inconsiderable beds of this mineral were known, among them those in California (1) and the Caucasus (2). But among the Inder boron minerals, hydroboracite is found to have a rather considerable propagation.

Information on the Inder hydroboracite is to be found in the works of Nikolaiev (3), Kurnakov, Nicolaiev and Tchilischtcheva (4), Boky (5), Volkoff (6), Kalinin and Nikolaiev (7).



However, hitherto hydroboracite was not obtained synthetically and, accordingly, the genetic connection existing between this mineral and other borates was never traced.

At Inder the paragenesis hydroboracite-gypsum is widely spread.

Calcium, being a stronger base, often displaces magnesium in borates, wherefore certain plausibility belongs to the hypothesis acording to which hydroboracite first came into being through an interaction between gypsum and magnesium borates (e. g. caliborite $KMg_2B_{11}O_{19} \cdot 9H_2O$ or pinnoite $MgB_2O_4 \cdot 2H_2O$). However, experiments conducted in our laboratory with a view of verifying this surmise failed to give any results, possibly, on account of very much time being needed to carry the work to a successful end. Our syntheses lasted 2 months, whereas 6 months are needed for the synthesis of invoite (8).

The synthesis of hydroboracite was effected in the following way: two solutions were taken, one, 100 g borax decahydrate in 450 cm^3 water; and the other, 50 g well annealed calcium chloride and 60 g magnesium chloride sexahydrate in 50 cm^3 water. These solutions were heated to boiling point, decanted and then left to stand with a prime of hydroboracite in a cucurbit with a return cooler at a temperatur of 50°. In 15 days the sediment became covered with a thick crust, under which it was possible to see through the microscope the formation of the first needle crystals. In a month these needle crystals were formed in large quantities (see microphotograph); however,

it was impossible to obtain them without any amorphous material. The refraction indices of the needlle crystals were found to be as follows:

$$N_g = 1.571; \quad N_m = 1.534; \quad N_p = 1.521.$$

The respective optical constants of Inder hydroboracite are:

$$N_g = 1.572; \quad N_m = 1.535; \quad N_p = 1.522.$$

The interference lines of the Debay-Scherrer exograph (copper emission) are analogous to those of native hydroboracite, but are not so clearly discernible, a fact which may be accounted for by the presence of amorphous matter. Chemical analysis gives the following picture:

$CaO = 12.82\%$; $MgO = 9.48\%$; $B_2O_3 = 50.88\%$; $H_2O = 26.82\%$;

$$\frac{B_2O_3}{RO} = 1.54.$$

Theoretical composition of hydroboracite:

$CaO = 13.58\%$; $MgO = 9.77\%$; $B_2O_3 = 50.54\%$; $H_2O = 26.12\%$;

$$\frac{B_2O_3}{RO} = 1.60.$$

Contents ob baric acid in liquid phase over sediment 1.35%. Ratio

$$\frac{B_2O_3}{RO} = 4.50.$$

Since synthetic hydroboracite is in mixture with amorphous matter and their separation is difficult, no determinations of specific gravity were made.

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CHEMISTRY

GALVANIC CELLS WITH FORMATION OF ALLOYS

By V. A. PLOTNIKOV, Corresponding Member of the Academy,

and D. P. ZOSIMOVICH

The electromotive force of the reversible galvanic cell is determined by the free energy of the process which generates the electric current. According to the generally adopted opinion the action of the galvanic cell of Daniel type consists in forcing out nobler metals by less noble ones. However, a galvanic cell may be constructed after the following scheme too: $Zn/ZnSo_4/Cu$. When the circuit is closed, the zinc electrode dissolves and zinc is deposited on the copper electrode. This process takes place on account of the change in free energy at the formation of a new crystal lattice corresponding to intermetallic compounds of copper and zinc or at the formation of solid solutions. We call such cells «galvanic cells with formation of alloys».

When the temperature of the process somewhat exceeds the eutectic temperature of depositing metal and metals on which the deposition takes place, there appears on the electrode a liquid eutectic that drips from its surface.

Let us consider the cell: (ternary alloy of bismuth, tin and lead) $/CdSO_4/$ cadmium. When this cell operates at the temperature of 70°, there appear on the ternary alloy drops of a quadruple eutectic (1).

As soon as the circuit is closed, the e. m. f. of the alloy cell quickly diminishes. While measured, it shows breaks corresponding to the intermetallic compounds, as it may be observed, for instance, with the cell mentioned above.

The higher rises the temperature, the more obvious become the breaks of the potential because atoms of the depositing metal diffuse at a high temperature easier into the electrode and on its surface constantly accumulate new quantities of intermetallic compounds. At a higher rate of diffusion the potential of the alloy retains its value longer than at a lower one. Is the diffusion insufficient, the surface of the electrode gets more atoms of deposited metal than they diffuse away and a new crystal lattice is formed with another quantity of free energy stored up—hence a new potential.

The deposition of base metal on a noble one has been observed by Raoult as early as in 1873 (2). He wreathed a wire of Zn, Sn or Cd around a golden or a silver plate, dipping it in the solution of salt of Zn, Sn or Cd. He found the noble metal covered with a layer of base metal. Later on the same phenomenon was investigated by Tammann (3). From the potential—time curve obtained after the stopping of the short circuit Tammann concluded that the depolarization curve of the metal could be put down to the oxidation of the deposited metal by oxygen.

He believed the noble metal electrode to become covered with a layer of less noble metal which diffuses into the noble metal. During his experiment he did not observe any visible precipitates.

Studying the galvanic cell $Zn/ZnSO_4/Cu$ we investigated the change of the e. m. f. with time at different temperatures (4).

The e. m. f. was measured by means of a potentiometer. During the experiment the cell was short-circuited and interrupted for 1—2 sec. Chemically pure copper and zinc were immersed into saturated solution of $ZnSO_4$ and the initial e. m. f. measured; then the cell was short-circuited and the change of e. m. f. with time was observed.

At 18° the e. m. f. of the cell decreases quickly enough from 980 mV to 10 mV. Because of the small rate of the e. m. f. the visible layer of zinc on copper appears on the third day. Only at 70—90° the e. m. f. changes somewhat slowlier, and the process of zinc deposition on copper becomes comparatively rapid: there is a slight, superficial, silvery-grey alloy of brass, depositing with a great content of zinc on the surface of copper. If we break the circuit of the cell that was closed during 60—100 min., the e. m. f. rises to its initial value in about 1—2 min. But if we disconnect the short-circuited cell after 25—30 days, the e. m. f. rises in 24 hours by 100—110 mV only. It is evident that in this case zinc has diffused deeply into copper. During one of our experiments after a short-circuiting that lasted 35 days we took a microphotograph on which the layer of brass could be seen very clearly (4).

In our last work we have investigated the changes of potentials in single electrodes (5). We experimented with the cell $Zn/N\ ZnSO_4/Cu$. Measurements were taken while short-circuiting by the compensation method on a round meterbridge with a 3-meter long wire. The reflecting galvanometer with $3 \cdot 10^{-9}$A sensitivity served as zero-instrument.

As standard electrode we use a calomel electrode with saturated solution of KCl. Measurements were taken at 18° C.

The electrodes were placed in a H-shaped vessel with cocks in each elbow serving to join the standard electrode. Both electrode potentials were measured at first; after closing the circuit we took potential measurements of copper (every 2 min.) and some measurements of the zinc potential. About 100 measurements were taken during each experiment. When experiments were repeated, the data coincided. A galvanometer and a resistance-box were switched in the external circuit of the cell.

At a great resistance in the external circuit the rate of the potential change is small; that enabled us to observe the breaks. The results of the measurements showed that the zinc potential did not undergo any significant change during the experiment and was equal to —0.790 V while the copper potential altered from +0.22 V to —0.70 V, it became more negative and approached the zinc potential.

Similar investigations have been carried out with galvanic cells in fused salts; with cells of this type we have at first observed the formation of aluminium alloys with copper and iron.

The cell Zn/ fused $ZnCl_2$/Cu has been studied at 380 ±5° C (4).

The e. m. f. of the cell decreases after short-circuiting but not with the same velocity as in the aqueous solutions, reaching 50—70 mV. When after the experiment the copper plate is taken out of the fused $ZnCl_2$, its colour varies from yellow to silvery-grey brass, according to the duration of the experiment.

40 min. give yellow alloys and 180 m.—silvery-grey ones. To judge from the colour, the brass obtained in the first case was α or β while at a longer experiment it was γ or η. The superficial layer of brass, formed after three hours, was 0.012 mm thick (a metallographic photograph).

The breaks of the e. m. f. —time curve suggested the conjecture that they corresponded to the alloy potential of the brass β and γ.

In order to find out the composition of brass formed on the copper plate in our cell, we deposited on the copper wire alloys corresponding to the breaks on e. m. f.—time curve and subjected them to an X-ray analysis (7).

The results of the measurements are tabulated below (Table 1).

Table 1

№ of samples	Time in min.	E. m. f. in mV with disconnected current	Supposed brass according to Sauerwald	Results of X-ray analysis			Control copper $a=3.619$Å
				Brass α	Brass β	Brass γ	
3	33	123	α	$a=3.675$Å	—	—	—
4	11	89	β	$a=3.670$Å	—	—	—
5	10	54	γ	$a=3.625$Å	$a=2.953$Å	—	—
6	30	48	γ	$a=3.629$Å	$a=2.961$Å	$a=8.841$Å	—

The deposited alloy № 6 had on its surface γ-brass; beneath it, β-brass; farther, α-brass; and at last, copper.

The table shows that according to Sauerwald (6) sample 4 ought to be β-brass, yet the roentgenogram shows α-brass; β-brass appears on the roentgenogram only in the sample 5, i. e. with a greater amount of deposited zinc.

In the same way, according to Sauerwald, experiment 5 ought to have shown γ-brass, yet the roentgenogram displays only the presence of α and β-brass, and γ-brass appears only in sample 6.

We think that the above-mentioned divergence of our results with the potentials of alloys studied by Sauerwald in dependence on the equilibrium diagram may be put down to the extreme thinness of the alloy layer at the beginning of its formation. This thin superficial layer gives a potential of the corresponding alloy, but the lines on the roentgenograms are so exceedingly feeble that they cannot be detected. The roentgenogram shows the reflection of deeper alloy layers resulting from the diffusion of zinc into copper.

The galvanic cell Al /fused $AlCl_3NaCl$/ Cu has been likewise studied at different temperatures. We obtained in this cell alloys of aluminium and copper which had different colours according to the temperature and duration of the experiment (8,9,10).

The measurements of the e. m. f. show a considerable diffusion of aluminium into copper. Roentgenographical investigations of copper-aluminium alloys give the following results (the exposure was identical for all the photographs) (Table 2).

As the temperature rises and approaches 300°, there may be noticed some enlargement of the copper lattice that proves the presence of the α-phase of Al-Cu alloy. Between 300° and 350° an intense recrystallization of the α-phase begins that can be clearly seen on the photos; feeble lines of the γ-alloy appear too. With rising $t°$, the amount of the α-phase on the electrode surface diminishes while the γ-phase increases (11).

Thus, the change of the e. m. f. of our galvanic cell reflects the process that takes place on the copper surface. Alloys are deposited gradually with an increasing content of less noble metal; therefore the potential of nobler

Table 2

№ of samples	Temperature of electrolyte	Time in min.	Results of roentgenographical analysis		Note
			parameter α-alloy Å	parameter γ-alloy Å	
1	200	60	3.600	—	—
2	200	180	3.601	—	—
3	300	60	3.606	—	—
4	300	180	3.607	—	—
5	350	60	3.601	8.690	2 feeble lines of γ-alloy
6	480	75	3.605	8.696	5 feeble lines of γ-alloy
7	500	15	3.606	8.700	5 feeble lines of γ-alloy
8	500	60	3.608	8.710	6 strong llnes of γ-alloy
9	550	60	3.608	8.702	6 strong lines of γ-alloy

electrodes approaches the potential of zinc or aluminium and the e. m. f. of the galvanic cell decreases gradually, approaching a very small value.

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GEOLOGY

MODE OF OCCURRENCE OF PERMIAN DEPOSITS IN THE NEIGHBOURHOOD OF THE TOWN OF KIRILLOV

By A. N. FEDOROV

(Communicated by A. A. Borissiak, Member of the Academy, 27. IV. 1938)

Numerous outcrops of Kazan carbonate rock are observed in the eastern part of the Leningrad region in the neighbourhood of the town of Kirillov, 30 km south-eastward from the White Lake; these rocks consist chiefly of limestones and marles partially dolomitized.

Five groups of such outcrops may be distinguished: 1) on the right-hand bank of the Sheksna river near the village of Ladunina, 2) on Mount Maur, 3) on Mount Sandyreva, 4) on Mount Zypina, 5) at the church yeard Ramenje near the village of Ustje.

The rocks exposed here have engaged the attention of geologists for a long time, first, because of the abundant and rather various fauna of the zechstein; secondly, in consequence of the disturbed mode of occurrence of the limestones, standing out of the background of the perfectly quiescent occurrence of the Permian beddings; thirdly, owing to the economic importance of these limestones which have been worked since olden days.

The fauna of the Permian limestones from the neighbourhood of the town of Kirillov has been monographically treated and described by Likharev ([3]), who has referred these limestones to the Lower Permian and later on ([4]) to the Kazan stage.

Much earlier Prof. Amalitzky ([1]) has suggested that the limestones worked on the right-hand bank of the Sheksna river, near the village of Ladunina, belong to the higher (conhifer) horizon of the Kazan stage, while the limestones composing the Maura, Sandyreva and Zypina Mountains are referred to the lower (Brachipoda) horizon.

This assumption has recently been refuted by a number of geologists who show that all the limestones in the neighbourhood of the town of Kirillov are of the same age.

The question as to the mode of occurrence of the Kirillov limestones and the nature of their disturbances is of much higher interest. While the determination of the exact age of these limestones is of chiefly scientific importance, the revelation of tectonic structures, accounting for the disturbed occurrence of rocks, is (apart from the scientific interest) of the highest practical importance, especially in the search for such useful minerals as gas and oil. It would, therefore, be very desirable, if structures fabourable for the occurrence of oil were found in the Leningrad region.

From the data by the majority of previous investigators [Kamanin (2), Lutkevich (5) etc., with the only exception of Ryabinin (6) and partly of Yaunputnin (7)], the Kirillov district was usually referred to as a dislocated area with a prevalent NE strike of dislocations, according to some (2), or with a latitudinal strike, according to others (5). In fact, the limestone beds in exposures of the Kirillov district are almost everywhere inclined NNW with angles of dip reaching 30—40 and even 47°.

The disturbed occurrence of these rocks has been interpreted by Kamanin (2) as due to a tectonic uplift at the surface, analogous to one of the uplifts of the Russian (east European) platform.

According to the observations of Lutkevich (5) who refers the disturbance of the rocks, near the town of Kirillov, to a tectonic folding, similar dislocations take place not only in the neighbourhood of Kirillov, but also further east, on the Uftyug river, north near the village Pidemskaya and considerably further southward, near the village of Abakanovo and the village of Myaksy in the Cherepovez district.

To find out the true nature of the Kirillov dislocations, the author undertook in 1936 a detailed geological research, on behalf of the Petroleum Institute, and established that all the dislocations observed in the Kazan deposits of the Kirillov district were due solely to the action of a glacier during the Quaternary.

Under the dislocated limestones of the zechstein glacial deposits were detected. Thus, e. g. at Mount Maur in one of the test-pits areno-argillaceous limestone containing Kazan fauna with a 295° NW dip at an angle of 28° was worked to a depth of 3—5 m; farther down Quaternary deposits were found lying in the following sequence:

1) Yellow boulder clay with pebbles and fragments of limestone and crystalline rocks and with lenses of gravel with small pebbles. Thickness 45—60 cm.

2) Red boulder clay with pebbles and fragments of limestone and crystalline rocks and lenses of sand, sometimes argillaceous. Thickness 94 cm.

3) Coarse grained sand of granitic composition with an admixture of calcareous grains. Thickness 13 cm.

4) Yellow banded clay. Thickness 50 cm. The beds are inclined 288° NW at an angle of 27°, i. e. the mode of occurrence is the same as above.

5) The same as layer 1. Thickness 29 cm.

6) Fine grained quartz-feldspar sand. Thickness 6—10 cm.

7) Yellow clay, slightly micaceous and finely arenaceous. Thickness 33 cm.

8) Yellow, banded, dust-like argillaceous sand with lenses of purer fine grained sand. Thickness 1.15 m.

9) The same as layer 7. Thickness 1.15 m.

Without dwelling any longer on the lit-par-lit section of the Quaternary deposits, it should be noted that the thickness of the latter in the Kirillov district is up to 50—60 m.

It is only under this thick Quaternary sheet that the Permian rocks lying in situ were reached by the drill. 20 km north-west of Kirillov near the village of Ustje, at the base of the Quaternary (depth 61.5 m) highly crusted limestones and calcareous clays have been detected with fauna of the Kazan stage (*Athyris pectinifera* Sow., *Athyris sandyrewensis* Lich., *Camaraphoria superstes* Vern., *Lingula credneri* Gein., etc.). The thickness of these breccia-like rocks was 15 m. Below Kazan rocks in an undisturbed state have been opened up. The limestone massifs located on the right-hand bank of the Sheksna river, 15 km east of Kirillov, which have been worked for a long time, proved to be only huge blocks of limestone transposed by a glacier.

An analogous mode of occurrence of the Kazan limestones and marls has been established also for other points of the Kirillov district.

Thus, it is proved that the Kazan rocks exposed in the Kirillov region lie not in situ, but have been «torn away» by glaciers. From this it follows that all the above considerations as to the «Kirillov dislocations» being a result of the action of tectonic forces are quite groundless.

Our investigations enable us to suggest a new scheme for the occurrence of tectonic rocks in the Kirillov area.

From the drill-hole sections it is established that the country rocks of this region are of a quiescent occurrence with a negligible dip to the south-east. The plunge of the beds is 2 m in 1 km which corresponds to a dip of 7'. Westwards from the town of Kirillov an almost imperceptible projection of the country rock directed to the south-east, i. e. almost across the general north-eastern strike, seems to take place. The projection is so insignificant that its eastern side is hardly distinguishable against the background of the general SE plunge of the beds, and the south-western side of the projection shows a dip of 4'.

Such a mode of occurrence points to an absence of folding in the Kazan and generally in the Permian deposits of the Kirillov region.

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MICROBIOLOGY

INFLUENCE OF BACTERIOPHAGE ON PHAGOCYTOSIS

By N. V. KAGAN

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It is well known that the mechanism of the action of the bacteriophage on the microbes is very complex and by no means confined to a mere dissolving of the latter.

Upon the introduction of the bacteriophage into the animal organism, there takes place an interaction of a number of factors, namely: 1) A phagocytosis of the bacteriophage itself by leucocytes, a fact already pointed out by D'Erelles. 2) An excretion of the bacteriophage from the organism. 3) A production of resistant races of microbes. 4) A change in the response of the microbes to the protective forces of the organism. In the literature some data are available indicating that microbes treated with bacteriophage undergo phagocytosis and agglutination in a manner different from that of the original normal culture.

Thus, Nelson has shown that an injection of bacteriophage to a rabbit increases the opsonization of those homologous cultures which are rather susceptible than resistant to the phage in question. The in vitro experiments of the same author revealed that the bacteriophage treated microbes undergo phagocytosis more actively than the non-treated control cultures.

Smith found the cultures of staphylococci susceptible to bacteriophage to rise their phagocytability abruptly when treated in vitro with a homologous bacteriophage. Upon treatment of resistant cultures with bacteriophage, their phagocytability remained unchanged. Hoder carried out a comparative study of the phagocytability of susceptible and resistant cultures of bacterium coli, staphylococci and bacterium of typhoid fever, etc. He succeeded in obtaining resistant variants which possessed a somewhat higher phagocytability than the original susceptible cultures. On the contrary, Hoss together with Jacobson found that the resistant variants are less subject to phagocytosis than the original susceptible cultures.

Thus, these rather scanty data are sufficient do draw the conclusion that the bacteriophage is capable in some way to change the properties of the microbe cells, making them more susceptible to phagocytosis.

Taking into consideration that all these questions were insufficiently discussed in literature, while the data available are somewhat conflicting, I undertook a detailed study of the influence of the bacteriophage on the phagocytability of microbes.

The work was performed using as material cultures of bacterium coli and staphylococcus and homologous bacteriophages. The bacteriophage

of b. coli, titre 10^{-9}, was obtained from Dr. M. I. Goldin (Institute of Microbiology of the Academy of Sciences of the USSR), the staphylococcus bacteriophage № 1, titre 10^{-6}, together with the susceptible culture, from Prof. V. A. Krestovnikov, and the staphylococcus bacteriophage № 2, together with the susceptible culture, from Prof. M. A. Morosov.

Methods. Various quantities of the bacteriophage diluted and non-diluted were added to 1.0% microbe emulsion (standard 12—40 milliards). The total amount of the liquid in the test tube was made to reach 5.0 by adding broth. 4.0 of broth was added to 1.0 of emulsion in the control test tubes. These conditions secured such a high concentration of microbes as made the lysis of the microbes no more possible, and only the absorption of the bacteriophage by the microbes was taking place. The test tubes were kept in a thermostat from 1 to 6 hours, after which the contents of the tubes were centrifugated and the remains of free bacteriophage washed off in saline.

In a number of experiments after leaving the test tubes for several hours at the temperature of 37°, they were placed overnight in a refrigerator and only then subjected to centrifugation. From the precipitate thus obtained diluted emulsions were prepared (standard 2 milliards). Equal quantities of each emulsion were mixed with the suspension of leucocytes of a guinea pig. After keeping the mixture in a thermostat for 45 min.—1 hour, smears were prepared and the phagocytes counted*. The opsonic index was determined as quotient of the phagocyte number obtained in the experiment with the culture treated with bacteriophage, divided by the phagocyte number of the control. Yet, in these experiments the bacteriophage exerted no influence upon phagocytosis.

All the experiments described above were made on leucocytes of a guinea pig. In order to eliminate any specific influence, in all my further experiments exclusively leucocytes of man were made use of. The method did not differ from that described above.

In the experiments with phagocytosis equal quantities of diluted emulsion and leucocytes were mixed in agglutination test tubes. The latter were placed for 10 min. into a steam-bath at a temperature of 40° C, after which smears were prepared. Fixation was done with methyl alcohol, the material stained after Gimza or with Manson blue. 200 cells mere counted from each smear.

The results of all the experiments with the culture of bacterium coli and staphylococcus are tabulated below. We see that the contact of b. coli with the bacteriophage for an hour failed to affect their phagocytability, since the opsonic index proved to be close to unity in all experiments. In those cases where the contact lasted up to 4 hours, we have noticed a pronounced increase of phagocytosis. On the average the opsonic index has been increased for 60% in this group of experiments, without noticing any effect of the bacteriophage added on the results of the experiments. With increase of the period of contact (4 hours at 37° and a night in the refrigerator), we find the index to approach unity very closely in some experiments, and even to decrease considerably in four of them. The average value of the opsonic index, however, lies for this group within 0.87—0.91.

The experiments with the culture of staphylococcus № 1 showed that a contact of the bacteriophage with microbes for an hour produced a marked increase of the index in the series of experiments (79% on the average) where 0.5 of bacteriophage had been added. In the experiments in which 0.4 of bacteriophage have been added, the index is 1 approximately. In those experiments in which the contact of microbes with the bacteriophage lasted 4 hours, the index was approaching unity in two cases out of eleven. In the rest of

* Phagocytes were counted in 200 cells of each smear.

Time and Temperature of the Contact

Culture		Dose of bacteriophage	1 hour at 37°			4 hours at 37°			4 hours at 37° and night spent in a refrigerator			24 hours at 37°		
			Number of experiments	Average opsonic index	Average increase of index in %	Number of experiments	Average opsonic index	Average increase of index in %	Number of experiments	Average opsonic index	Average increase of index in %	Number of experiments	Average opsonic index	Average increase of index in %
Bacterium coli	Living culture	0.5	3	1.01	—	4	1.61	61	5	0.91	—	—	—	—
		4.0	3	1.0	—	4	1.6	60	3	0.87	—	—	—	—
Staphylococcus № 1	Living culture	0.5	3	1.79	79	6	1.5	50	4	1.4	40	—	—	—
		4.0	4	0.93	—	5	1.67	67	4	1.38	38	—	—	—
	Killed culture	0.5	—	—	—	5	1.57	57	2	1.57	57	—	—	—
		4.0	—	—	—	5	1.55	55	2	1.63	63	1	1.7	70
Staphylococcus № 2	Living culture	0.5	1	1.0	—	3	—	—	—	—	—	—	—	—
		4.0	1	1.0	—	3	—	—	—	—	—	—	—	—

experiments it is considerably higher, reaching 100% and sometimes even 130%. A somewhat smaller increase was observed in the group of experiments in which the test tubes after having been kept four hours at a temperature of 37° were placed for the night into a refrigerator. The increase of the opsonic index in this group amounted to 40% on the average.

Let us now proceed to the experiments performed with killed cultures of staphylococcus № 1. The cultures were killed with formalin (dropping through a cotton wool stopper). Otherwise the method of the experiments did not differ from that described above. As may be seen from the table, the killed microbes having absorbed the bacteriophage became more susceptible to phagocytosis. Only in three cases out of 15 of this series no increase of the opsonic index could be observed. In all other cases the opsonic index has increased, in some of them even considerably (190%). In this group of experiments we observed on the average an increase of the index for 55—63%, i. e. approximately the same as in the experiments with living cultures.

This table also includes the results of the experiments with the culture of staphylococcus № 2. On the whole, as it may be seen from the table, 8 experiments were performed in various combinations. No increase of the opsonic index caused by bacteriophage was noted, and experiments with this culture were abandoned.

We have also undertaken several experiments for the study of phagocytability of the four resistant variants obtained from the original susceptible culture of staphylococcus № 1. The opsonic index in all experiments was very close to unity.

The data given above allow us to come to the conclusion that after a contact with bacteriophage the microbial cells can change and become susceptible to phagocytosis. Though neither all cultures nor all kinds of bacteriophage behave in the same way. Thus, in the cultures of bacterium coli a noticeable increase of the opsonic index occurs only in one series in which the

contact between the microbes and the bacteriophage lasted two hours. In the case of experiments where the contact exceeded that period, the opsonic index proved even to be considerably lowered.

It seems worthy to note that in the experiments in which the contact between the microbes and the bacteriophage lasted over 4 hours (4 hours at the temperature of 37° and a night in the refrigerator in the experiments with staphylococcus № 1), we frequently observed a decrease of the index.

This may possibly be attributed to the fact that with such a lasting action of the bacteriophage a part of the susceptible microbial cells perish and a selection of resistant microbes takes place, i. e. of those which are less susceptible to phagocytosis. On the other hand, we may deal with a phenomenon, similar to the «stopping zone», sometimes observed in serological reactions.

The staphylococcus bacteriophage № 1 proved to be more active than bacteriophage. This may possibly be due to the qualitative difference between the two kinds of bacteriophage, their different affinity to cultures, as for instance, the capacity of bacteriophage № 1 to lizate a culture immediately and entirely.

In the experiments confined to the study of the phagocytability of cultures of staphylococcus № 1, resistant to the bacteriophage, we failed to observe any essential difference between these variant and the original susceptible culture, although the material is far from being sufficient to arrive at a definite conclusion.

Conclusions

In experiments in vitro under the influence of the interaction of homologous bacteriophages and the cultures of b. coli and staphylococcus, the bacterii acquire a more intense phagocytability. However, this phenomenon is not expressed in the same degree in different strains. In certain cultures it may be entirely lacking.

Killed microbes, as well as living ones, pass phagocytosis more actively after a treatment with bacteriophage than original non-treated cultures.

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GENETICS

NEW DATA ON THE MORPHOLOGY OF RYE CHROMOSOMES

By E. N. SHMARGON

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The first data on the morphology of rye chromosomes were obtained in 1930—31 by Lewitsky ([1,4]) by the aid of a special method of chrom-formalin fixation which he introduced into cytological practice. By this method it proved possible to make out the primary articulation of the chromosomes into two arms, and one pair of chromosomes with large «appendages» was noted as being sharply distinct from the others. All the chromosomes were subjected to accurate measurement after a method especially devised for this purpose.

Fig. 1.

Later the morphology of rye chromosomes was studied by Hasegawa ([2]) during the first division of pollen grains after the aceto-carmine method. This author also obtained plates showing the primary articulation of the chromosomes, on the basis of which he divides, without giving a detailed idiogram, the haploid set into three chromosomes of different lengths with a submedian constriction, three, also of various lengths, with a median constriction, and one chromosome with an «appendage» on the shorter arm.

In 1934 Lewitsky ([3]) published the formulae for a number of new perfected fixatives for bringing out the morphology of chromosomes. Of these the one giving the best results for cereals is the so-called «strong platinic formalin» solution (equal parts of 2% platinum chloride and 50% formalin). This fixative was used in the present investigation.

Root-tips of rye, prior to fixation, were cooled for 24 hours at 0° C, in order to contract and straighten out the chromosomes. Microtome cuts were made 16 μ thick and stained with iron haematoxylin. Using this method of treatment it was possible to detect, apart from the «appendages» already known, satellites on four pairs of chromosomes and secondary constrictions on one pair. There remained only two pairs of chromosomes lacking secondary constrictions and markedly differing in size (Fig. 1 and 2). For the purpose of making a detailed study of the morphology of chromosomes they were measured according to Lewitsky's method ([1]). Metaphase chromosomes (Fig. 1) were taken for measurement, and on the basis of the data obtained there was drawn up a «quantitative diagram» (Fig. 3). The chromosomes in this diagram are arranged according to their length.

In calculating the ratios between the lengths of the arms, I include both the «appendage» and the satellite with its connecting thread in the length of the arm to which they were attached. From Fig. 1 and 3 and the data given in the table (p. 45) the morphology of rye chromosomes may be described as follows.

The two longest pairs of chromosomes (I and II) are practically equal in length (8.9 μ and 8.7 μ), have similar ratios between the lengths of their arms (2.4 : 1 and 2.3 : 1), and possess similar satellites attached to their short arms. These satellites may sometimes be observed, when the chromosomes are fixed with chrom-formalin, in the shape of comparatively large heads separated by a constriction (IV, Fig. 3; V, Fig. 1 and 2). As a rule, however, when this method is used, they are concealed in the chromatin matrix. This accounts for their being included in the length of the arm measured. The first pair is, however, distinguished from the second one by the presence of a secondary constriction on the long arm. The chromosomes

Fig. 2.

Fig. 3.

of pair III are shorter, but have satellites too, and the ratio between the lenghts of their arms is somewhat different (2.0 : 1 and 2.1 : 1). All the three pairs have markedly unequal arms.

The chromosomes of pair IV (8.0 μ and 7.7 μ long) have almost equal arms, and are lacking secondary constrictions. The chromosomes of pair V (7.7 μ and 7.6 μ long; ratio of arms 1.2 : 1 and 1.4 : 1) differ markedly from the rest, owing to the presence on the smaller arm of «appendages» (0.8—0.9 μ long) separated from it by a broad «achromatic zone». The chromosomes of pair VI (7.1 μ and 6.8 μ long) and of pair VII (7.0 μ and 6.8 μ long) are almost equal in length and in the ratio between the lengths of their arms (1.2 : 1), but differ in that the chromosomes of pair VI have satellites sometimes on both arms (Fig. 2).

A comparison of Lewitsky's, Hasegawa's and my data shows the same general distribution of rye chromosomes: three almost equal-armed chromosomes, three markedly unequal-armed, and one bearing an «appendage».

However, a more detailed comparison of chromosome measurements made by Lewitsky and myself (the table) shows a considerable discrepancy. Thus, according to my data, the chromosome with the «appendage» does occupy, as regards length, not the second place, but the fifth one. However, this makes up a total difference in length of no more than $^3/_4$—1 μ, caused, presumably, by the greater contraction (as a result of the cooling prior to fixation) of the «achromatic zone» which, in general, is liable to sharp length variations (according to Lewitsky, from 1.1 μ to 0.4 μ). The ratios between the lengths of the arms in these definitely distinguishable chromosomes in both cases coincide (1.2 : 1). Taking into account the insignificant diffe-

rences in the total length of separate chromosomes of the set and the marked differences in the ratios between the lengths of the arms, the latter were used for comparison in the table. In five pairs these data exactly coincide. The disagreement in the case of the remaining two pairs may possible be accounted for by structural chromosome differences within a species, numerous cases of which have already been reported ([6],[7],[8]), including one case in rye ([9]).

Comparison of Data on Chromosome Measurements (*Secale cereale*)

Shmargon					Lewitsky (1931)				
Chrom. pair	Total length of chrom. (in μ)	Length of long arm (in μ)	Length of short arm (in μ)	Ratio of arms	Chrom. pair	Total length of chrom. (in μ)	Length of long arm (in μ)	Length of short arm (in μ)	Ratio of arms
I^{I}	8.9	6.3	2.2+0.2+0.2	2.3:1	I^{I}	10.0	6.05	3.95	1.5:1
I^{II}	8.8	6.2	2.2+0.2+0.2	2.4:1	I^{II}	10.0	6.1	3.9	1.6:1
II^{I}	8.8	6.2	2.2+0.2+0.2	2.4:1	VI^{I}	9.05	5.7	3.35	1.7:1
II^{II}	8.7	6.1	2.1+0.3+0.2	2.3:1	VI^{II}	8.8	5.5	3.3	1.7:1
III^{I}	8.4	5.6	2.4+0.2+0.2	2.0:1	VII^{I}	8.15	5.55	2.6	2.1:1
III^{II}	8.4	5.7	2.3+0.2+0.2	2.1:1	VII^{II}	8.0	5.4	2.6	2.1:1
IV^{I}	8.0	4.5	3.5	1.3:1	III^{I}	9.6	5.5	4.1	1.3:1
IV^{II}	7.7	4.2	3.5	1.2:1	III^{II}	9.4	5.2	4.2	1.2:1
V^{I}	7.7	4.2	2.2+0.4+0.9	1.2:1	II^{I}	9.75	5.35	4.4	1.2:1
V^{II}	7.6	4.4	1.9+0.5+0.8	1.4:1	II^{II}	9.8	6.45	4.35	1.2:1
VI^{I}	7.1	3.9	2.8+0.2+0.2	1.2:1	V^{I}	9.25	4.75	4.5	1.1:1
VI^{II}	6.8	3.6	2.8+0.2+0.2	1.1:1	V^{II}	8.6	4.3	4.3	1.0:1
VII^{I}	7.0	3.9	3.1	1.2.1	IV^{I}	9.7	5.0	4.7	1.1:1
VII^{II}	6.7	3.7	3.0	1.2:1	IV^{II}	9.5	5.0	4.5	1.1:1

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GENETICS

BLOOD COMPOSITION IN SHEEP AND THEIR HYBRIDS WITH *OVIS POLII KARELINI* (SEV.) IN CONNECTION WITH THE POWER OF ACCLIMATIZATION

By H. F. KUSHNER and O. N. KITAIEVA

(Communicated by N. I. Vavilov, Member of the Academy, 16. IV. 1938)

The Department of Animal Genetics of the Institute of Genetics of the Academy of Sciences has been experimenting since 1933 in the creation of a new breed of sheep in Kirghisia and Kazakhstan by crossing Merinos with the *Ovis polii Karelini*; the new breed should combine the high wool productivity of the Merino with the power of the *Ovis polii Karelini* to adapt itself to high altitude environment.

Naturally enough in these experiments and generally in connection with the problem of extending Merino breeding into the mountains to an altitude of about 3000 m, great attention must be paid to the power of the animals to adapt themselves to high altitude environment. Among the soil, climatic and other conditions, which obstruct fine wool sheep-breeding in mountainous regions, the reduced content of oxygen in the air plays a very essential part. Naturally, in high altitude conditions the organism of the animal should undergo such physiological changes as would secure to it an adequate quantity of oxygen: in addition to a quicker pulse and breathing there is also a greater oxygen carrying capacity of the blood which finds its expression in an increased number of erythrocytes and in a higher haemoglobin value. The most extensive work in this line has been done by Abderhalden (3), Duerst (6), Barcroft and Bürker (4). The experiments by Bürker and his associates (5) have clearly demonstrated the part played by blood under conditions of a scarcity of oxygen. Experimenting with rabbits and dogs the authors have found that the number of erythrocytes as well as the haemoglobin content increase shortly after the function of one of the lungs has been surgically eliminated and that as a result of such an increase in the oxygen carrying capacity of the blood of the animals tested the oxygen scarcity is to a certain extent compensated.

Thus, starting from the fact that blood value is of great importance for the acclimatization of animals in mountainous environment, we set ourselves the task to find out the physiological features distinguishing hybrids from local Kirghiz sheep and the Merino.

During the period beginning with September 26 and ending October 14 1937, we have examined the hybrids and Merinos on the state farm «Ilyitch» in the Kirghiz Soviet Socialist Republic and the local fat-tail dams of the Kirghiz breed on a neighbouring farm (Djanny-Djol), within a distance of 3 km from the state farm. At that time the sheep were on farms situated at an altitude of 1500 m above sea level.

Altogether 345 animals were examined for blood. Among these animals there were:

1. Ninety Merinos of the New-Caucasian and Precoce types (including young sheep).

2. Seventeen F_1 (N-C×O.p. K), hybrids from a cross between *Ovis polii Karelini* and local Merino dams of the New Caucasian type (half-bloods of the *Ovis polii Karelini*).

3. Nine F_1(K × O. p. K), hybrids from a cross between *Ovis polii Karelini* and local fat-tail dams of the Kirghiz type (half-bloods of the *Ovis polii Karelini*).

4. Sixty two F_2(N-C×F_1), hybrids from a cross between sires of the F_1(N-C×O. p. K) and Merino dams of the New-Caucasian type (quarter-bloods of the *Ovis polii Karelini*).

5. Sixty six F_2(P×F_1), hybrids from a cross between sires of the F_1 (N-C×O. p. K) and Precoce dams(quarter-bloods of the *Ovis polii Karelini*).

6. Fifty four F_2(K×F_1), hybrids from a cross between sires of the F_1 (K×O. p. K) and fat-tail dams of the Kirghiz breed (quarter-bloods of the *Ovis polii Karelini*).

7. Five F_2(G×F_1), hybrids from a cross between sires F_1(K×O. p. K) and fat-tail dams of the Guissar type (quarter-bloods of the *Ovis polii Karelini*).

8. Four F_2(F_1×R), from a cross between Rambouillet sires and dam hybrids F_1(N-C×O. p. K) (quarter-bloods of the *Ovis polii Karelini*).

9. Twenty four local fat-tail dams of the Kirghiz breed.

10. Fourteen complex and other hybrids.

Blood was taken from the jugular vein in the morning hours, food and water having been withheld from the animals during the night. Blood was tested for haemoglobin, number and size of erythrocytes and alkalinity reserve.

The haemoglobin value was determined by means of a Sahli haemometer and Thoma-Zeiss camera was used in counting the number of erythrocytes, the blood being diluted 200 times. To determine the diameter of erythrocytes dry smears were taken; the magnification was 2400, an ocular micrometer being made use of. Blood alkalinity was determined after Nevodov's method.

The difference in the body weight of the groups of animals examined by us is given in Table 1.

Table 1

Difference in Body Weight of Sheep Grouped According to Breed

Breed	Body weight in kg					
	Rams, 6 months old		Ewes, 18 months old		Dams	
	n	*M*±*m*	*n*	*M*±*m*	*n*	*M*±*m*
Precoce	25	35.54±0.87	10	52.2±1.5	15	57.26±1.3
New-Caucasian Merinos	—	—	25	46.6±0.9	—	—
Kirghiz	—	—	—	—	24	55.08±1.008
F_1 (N-C×O. p. K)	—	—	—	—	9	50.5 ±0.96
F_1 (K×O. p. K)	—	—	—	—	3	56
F_2 (P×F_1)	29	30.62±0.66	4	51.5*	—	—
F_2 (N-C×F_1)	20	29.58±0.99	—	—	—	—
F_2 (F_1×R)	4	36.2	—	—	—	—
F_2 (K×F_1)	—	—	31	53.25±1.2	—	—
F_2 (G×F_1)	—	—	3	59.66	—	—

* The sires of these hybrids F_2 were hybrids of the first generation from a cross between *Ovis polii Karelini* and fat-tail dams; their mothers were thoroughbred Precoce.

Table 2

Indices in Blood of Sheep

Breed and age of animals	Male					Female				
	Head, n	Haemoglobin in Sahli units $M \pm m$	Number of erythrocytes in millions per 1 mm³ $M \pm m$	Blood alkalinity in mg % $M \pm m$	Diam. of erythrocytes in microns $M \pm m_{\Sigma}$	Head, n	Haemoglobin in Sahli units $M \pm m$	Number of erythrocytes in millions per 1 mm³ $M \pm m$	Blood alkalinity in mg % $M \pm m$	Diam. of erythrocytes in microns $M \pm m_{\Sigma}$
Six months old (born 1937)										
Precoce	25	52.4 ±1.32	10.057±0.35	520 ± 8.6	4.56±0.06	—	—	—	—	—
F_2 (P×F_1)	29	54.8 ±1.42	10.2 ±0.48	510 ±12	4.67±0.057	31	57.76±1.7	10.786±0.46	518 ±13.6	4.61 ±0.058
F_2 (N-C×F_1)	20	56.76±1.7	10.896±0.496	512 ±14	4.66±0.065	42	53.1 ±1.68	9.724±0.46	492.8±11.6	4.643±0.058
F_2 (F_1×R)	4	51.67	9.972	490	4.63	—	—	—	—	—
Eighteen months old (born 1936)										
Precoce	—	—	—	—	—	10	60.9 ±1.76	11.295±0.468	548 ±22.8	4.57 ±0.068
N-C. Merinos	—	—	—	—	—	25	56.86±0.85	10.43 ±0.27	526.4± 9.8	4.59 ±0.054
F_2 (K×F_1)	10	55.9 ±2.5	10.145±0.719	548±22.2	4.7 ±0.10	44	59.3 ±1.47	10.805±0.39	520.8±10.5	4.56 ±0.052
F_2 (P×F_1)*	2	62.9	10.95	550	4.635	4	58.25	10.6	480	4.66
F_2 (G×F_1)	2	62.5	12.27	600	4.55	3	64.6	12.94	533.4	4.45
Adult (born in 1934 and 1935)										
Precoce	—	—	—	—	—	16	59.13±1.32	11.17 ±0.312	570 ±21.9	4.59 ±0.07
Merinos**	14	55.65±1.5	10.436±0.267	495±19.3	4.69±0.04	—	—	—	—	—
Kirghiz	—	—	—	—	—	24	52.55±0.91	9.96 ±0.19	577.4±15.7	4.53 ±0.065
F (K×O. p. K)	4	59.5	11.115	525	4.77	5	67.46±1.17	13.196±0.28	595 ±15.2	4.704±0.051
F_1 (N-C×O. p. K)	8	66.1 ±1.78	12.2 ±0.51	562.8±14	4.78±0.068	9	63.3 ±4.56	11.274±1.226	554 ±31.5	4.84 ±0.106

* The sires of these F_2 hybrids are hybrids of the first generation from a cross of the *Ovis polii Karelini* and fat-tail dams while their mothers are thoroughbred Precoce.

** The group «Merino rams» includes sires of the New-Caucasian type, Precoce and Rambouillet between five and eight years of age.

Table 3

Difference in Blood Indices Between Sheep and Their Hybrids with *Ovis polii Karelini* (Sev.)

Groups compared	Haemoglobin		Number of erythrocytes		Blood alkalinity		Diam. of erythrocytes	
	$D + m_d$	P	$D + m_d$	P	$D + m_d$	P	$D + m_d$	P
Precoce dams and Kirghiz dams . .	6.58±1.603	100	1.21 ±0.365	99.9	− 7.4±26.98*	23	0.062±0.095	45
Precoce ewes and New-Caucasian ewes (18 months old)	4.04±1.95	96	0.865±0.54	89	21.6±24.8	63	−0.02 ±0.086	16
Hybrid F_1 (N-C × O. p. K) rams and Merino rams	10.45±2.33	100	1.764±0.583	99	67.8±23.8	98.9	0.09 ±0.085	70
Hybrid dams F_1 (K × O. p. K) and F_1(G × O. p. K) and Kirghiz dams.	14.91±1.48	100	3.236±0.338	100	17.6±21.8	57	0.176±0.082	96
Hybrid F_1 (N-C × O. p. K) dams and Precoce dams	4.17±4.74	63	−0.10 ±1.26	8	16.0±38.2	31	0.25 ±0.12	96
Hybrid F_2 (M × F_1)** rams and Precoce rams (six months old) . .	3.2 ±1.74	93	0.423±0.506	57	— 9.0±12.8	51	0.1 ±0.079	80
Hybrid F_2 (P × F_1) ewes and hybrid F_2 (N-C × F_1) ewes (six months old)	4.66±2.39	95	1.062±0.65	89	25.2±17.8	84	−0.033±0.08	31

* In general the differences are shown in favour of the first of the groups compared; wherever a minus occurs before the first figure, it signifies that the difference is in favour of the second of the groups compared.

** This group combines hybrids F_2 (P × F_1) and F_2 (N-C × F_1).

Precoce take the first place in the group of dams. The Kirghiz come next, falling short by not more than 2.2 kg. As to the hybrid dams F_1, those derived from the fat-tail breed and from the New-Caucasian Merino, are both inferior to the thoroughbred Precoce; the advantages of the latter over the hybrids from the New-Caucasian dams are particularly significant.

The results of the analyses of the blood are shown in Table 2.

The difference in the blood indices and the significance (according to Student-Fisher's tables) of these differences in the groups examined by us are shown in Table 3.

The figures of this table permit us to draw some valuable conclusions.

First, the blood indices of the hybrids in all the age and sex groups are considerably higher than those of the local fat-tail sheep and the Merinos of the New-Caucasian type. This refers to hybrids both from fat-tail dams and merinos of New-Caucasian type. This distinguishing feature of the hybrids is an outcome of the fact that the respective blood indices of the wild *Ovis polii Karelini* are much higher than those of the domestic sheep as proved by the data given by Bairov (1). The larger number and size of the erythrocytes contained in the blood of hybrids, compared with those of the domestic sheep, account for the greater oxidative surface of the erythrocytes in each volume unit of the blood.

The low blood indices of the local Kirghiz sheep is accounted for by the particular constitution and the particular metabolism of the fat-tail sheep.

Furthermore, stress should be laid on the interesting features of the blood values of the Precoce type which favourably distinguishes it from the New-Caucasian Merino type. We have shown previously that the Precoce is superior to the New-Caucasian Merino type and to the hybrids both in regard to the body weight of the adult animal and the growth of youth. The quality of the wool of the Precoce sheep is also high. It would therefore be of great advantage for our sheep-breeding industry if we succeeded in acclimatizing the Precoce in the higher altitude Alpine pastures. Comparing from this point of view the blood indices of the groups of sheep given previously, particular attention should be paid to the high values of the Precoce in regard to haemoglobin content and number of erythrocytes. As far as these values are concerned, the Precoce dams are much superior to the Kirghiz dams; the young Precoce ewes born in 1936 are likewise by far superior to the young New-Caucasian Merino ewes in regard to these factors, and, finally, the blood value of the young hybrids born in 1937 of Precoce dams is much higher than that of the hybrids born of New-Caucasian dams. Comparing Precoce dams with hybrids F_1 born of Merino dams, we find that the blood value of the former is only slightly inferior to that of the hybrids. Taking into account also the breed qualities of the Precoce we make bold to express the opinion that this type possesses certain qualities which make it fit to be bred in mountainous

Table 4

Red Blood Constants of Sheep

Groups	R	Du	Di	O_1	O_{100}	V_1	V_{100}	Hgl_{100}	Hgl_1	L_{100}
Precoce dams . .	11.17	4.59	1.62	48.62	54.4	22.7	25.4	10.25	9.18	220
Kirghiz dams . .	9.96	4.53	1.57	47.0	46.8	21.6	21.5	9.08	9.1	198
F_1 (K×O. p. K) dams	13.19	4.70	1.65	50.8	66.9	24.5	32.3	11.7	8.9	245
F_1(N-C.×O. p. K) dams	11.27	4.84	1.69	53.6	60.4	26.4	29.7	11.0	9.75	224

regions and that wide experimental work should be encouraged in this direction.

In conclusion we give in Table 4 some blood constants generally accepted in literature and calculated after the Götze method (8) on the basis of our analyses.

This table serves to show that along with the hybrids the Precoce dams also show a relatively high oxidative capacity of the blood (O_{100}, L_{100}, Hgl_{100}, R), which is an indirect proof that this type possesses good physiological qualities permitting it to adapt itself to mountainous conditions.

We have previously established (2) the regular principle that within the limits of a group of a homogenous type of sheep the animals with a bigger body weight show higher blood indices both in regard to haemoglobin and number of erythrocytes. As further proof of this principle we give below in Table 5 respective data for the largest groups of animals involved in the present investigation.

Table 5

Blood Value Differences in Connection with Body Weight

Groups	Head, n	Plus variant of body weight			Minus variant of body weight		
		Haemoglobin content in Sahli units	Blood alkalinity in mg %	Number of erythrocytes in millions	Haemoglobin content in Sahli units	Blood alkalinity in mg%	Number of erythrocytes in millions
F_2 (K×F_1) ewes 18 months old . . .	44	61.6	540	11.02	55.78	497	10.45
Precoce rams six months old . . .	25	54.3	516	10.34	50.87	522.8	9.84
F_2 (P×F_1) ewes six months old . . .	31	60.56	543.6	11.55	54.76	490	9.97
F_2 (N-C × F_1) ewes six months old .	42	52.2	487.4	9.64	52.51	492	9.46

This table thus confirms the regularity of the principle established by us in the case of all animals except those in the group of hybrid ewes from New-Caucasian Merinos: higher blood value is related to a bigger body weight.

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HAPLOIDS AND HAPLO-DIPLOIDS AMONG HYBRID TWIN SEEDLINGS IN WHEAT

By A. S. KASPARYAN

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In wheat, as well as in a number of other crop plants, seeds are occasionally encountered which give rise to two, or sometimes even to three seedlings.

In 1937 we investigated seven pairs of such twin seedlings of wheat. Four of them were found by E. I. Nikolaienko among the F_1 from a cross between different geographical forms of hard wheat (material of N. I. Vavilov); one pair was found among the F_1 from a cross between soft wheat and wild emmer and two among soft wheat plants (our own material which had been subjected to high-temperature treatment during the first divisions of the zygote). At early stages of development the two plants of each pair of twins were carefully separated with a razor and potted.

As may be seen from the table below, in two of the seven pairs of twin seedlings one of each pair was haploid, in two others haplo-diploid (i. e., contained a haploid set from one parent and a diploid set from the other), while in three both seedlings were normally diploid.

№	Hybrids and species of wheat giving rise to the twin seedlings	Somatic chromosome numbers in the twin seedlings	
		I	II
1	*Tr. durum quasi-affine* (2n=28)×*Tr. durum hordeiforme* (2n=28)	28	14
2	*Tr. durum melanopus* (2n=28)×*Tr. durum leucurum* (2n=28)	28	42
3	*Tr. durum melanopus* (2n=28)×*Tr. durum leucurum* (2n=28)	28	28
4	*Tr. durum leucurum* (2n=28)×*Tr. durum melanopus* (2n=28)	28	28
5	*Tr. vulgare erythrospermum* (2n=42)×*Tr. armeniacum* (2n=28)	35	49
6	*Tr. vulgare erythrospermum* (2n=42)	42	21
7	*Tr. vulgare erythrospermum* (2n=42)	42	42

The twin plants from the cross *Tr. durum quasi-affine* (Cyprus)×*Tr. durum hordeiforme* 010 (Dniepropetrovsk) differed from each other from the very beginning of development. The seedlings were not of the same size, the

larger being a diploid hybrid ($2n=28$) and the smaller a haploid one with 14 as its somatic chromosome number. After the development of the first leaves it was found that the haploid plant, like the mother plant *Tr. durum quasi-affine*, was liguleless. At maturity the haploid was shorter (65 cm) than the diploid (83 cm), differing from it by its narrower, shorter leaves, smaller heads with a smaller number of spikelets per head, and with narrower outer glumes and thin, delicate awns (Fig. 1). The pollen of the diploid plant was normal, while that of the haploid was completely sterile. The diploid was normally fertile; the haploid, when self-polli-

Fig. 1. Fig. 2. Fig. 3.

Fig. 1. A diploid and a haploid spike of *Tr. durum quasi-affine*×*Tr. durum leucurum*, and somatic plate from the haploid.

Fig. 2. A diploid and a haplo-diploid spike of *Tr. durum melanopus*×*Tr. durum hordeiforme*, and somatic plate from the haplo-diploid.

Fig. 3. A diploid and a haploid spike of *Tr. vulg re erythrospermum*, and somatic plate from the haploid.

nated, was sterile, but, when pollinated with pollen from *Tr. Timopheevi*, there set one seed.

The twin seedlings from the cross *Tr. durum melanopus* 069×*Tr. durum leucurum* (Sardinia) also differed beginning with the first stages of development. The larger seedling was a diploid hybrid ($2n=28$); the smaller, which was darker green in colour, was a haplo-diploid ($2n=42$). This plant did not tiller at all, when mature proved considerably shorter (75 cm) than the diploid (105 cm) and was readily distinguishable by its dark green colour. The spike and all parts of the spike were increased as compared with the diploid plant (Fig. 2). Its pollen grains greatly varied in size, and about 30% were sterile. The fertility of the haplo-diploid was low; with open pollination only three seeds set.

In the case of the twin seedlings from *Tr. vulgare erythrospermum* («Novinka»), just as in the first case, the larger seedling was normally

diploid ($2n=42$), while the smaller was haploid, its somatic chromosome number being 21. Prior to heading the twin plants were almost indistinguishable from each other. At maturity the haploid was somewhat taller than the diploid, and its spikes were longer and narrower (Fig. 3). The haploid could be safely distinguished from the diploid only by its complete sterility. After pollination with pollen from *Tr. durum hordeiforme* there set three seeds.

Both seedlings of the pair of twins from the cross *Tr. vulgare erythrospermum*×*Tr. armeniacum* were hybrid, but while the larger was a normal hybrid ($2n=35$), the smaller had a double set of paternal chromosomes ($2n=49$).

At the first stages of development the 49-chromosome plant was distinguished by its considerably denser pubescence, typical of the paternal form. At maturity it was somewhat shorter than the normal hybrid plant.

All parts of the flower, spikelets, and spikes were somewhat larger (Fig. 4). The pollen of this 49-chromosome plant, although varying in size of granules, was, judging by external appearance, about 80% normal, and fertility, under conditions of open pollination, attained 12%, while the pollen of the normal hybrid plant was almost completely sterile and the F_1 was infertile (Fig. 5).

According to the investigations of E. N. Makushina, *Tr. dicoccoides* ssp. *armeniacum* gives absolutely sterile progeny not only when crossed with soft wheat, but also when crossed with all other wheats, even with *Tr. dicoccoides*. This has made it necessary to give this subspecies the rank of a real species, *Tr. armeniacum*. The above-described doubling of the chromosome set of *Tr. armeniacum* in the hybrid results, as we see, in an entirely different behaviour of the hybrid progeny as regards fertility. This case points once more to the great importance of polyploidy in hybridization.

Fig. 4. The 35 and 49-chrom. plants from the cross *Tr. vulgare erythrospermum*×*Tr. armeniacum* and somatic plate from the 49-chromosome plant

During the past few years a number of papers have appeared on twin seedlings, however, these seedlings were as a rule obtained from no hybrid material ([1–6]). Of the seven pairs of twin seedlings investigated by us, five were F_1 hybrids, which made it possible in several cases to establish quite definitely the participation of the maternal and paternal genoms and, consequently, to approach nearer to an understanding of the mechanism of origin of twin seedlings. There have been no direct embryological investigations as to the mode of origination of twin seedlings and their chromosomal aberrations except for those reported by Kappert ([7]). This author succeeded in observing flax twin embryos during the embryonic stage of development, yet he was unable to determine which elements of the embryo-sac gave rise to them. Work in this field is very difficult, owing to the insignificant ratio of twin seedlings occurring. An investigation of them in the first hybrid generation is therefore of particular interest. Thus, the fact that the haploid plant of the pair of twin seedlings from the cross *Tr. durum quasi-affine*×*Tr. durum hordeiforme* was, like the initial maternal form, liguleless, does undoubtedly indicate that the initial cell for this seedling was either an extra egg-cell or an antipodal or synergid cell, which assumed the functions of an egg-cell and was stimulated to development without fertilization.

Still more illuminating is the case of the occurrence of a plant with the double set of paternal chromosomes, one of the pair of twin seedlings from the cross *Tr. vulgare erythrospermum* × *Tr. armeniacum*, which controverts the opinion prevailing heretofore that triploids among twin plants arise as a result of the ability of endospermic cells to develop into embryos ([5],[7]). Our haplo-diploid, in all probability, arose in the following manner: there penetrated into the embryo-sac extra sperms, either as a result of the germination of two pollen tubes or as a result of a division of sperms in one pollen grain. One pair of sperms caused the formation of the normal hybrid plant and endosperm; the second pair, or one sperm with an unreduced chromosome number (which is less probable, since *Tr. armeniacum* normally does not form diploid gametes), having fused with an extra egg-cell or with an antipodal or synergid cell, gave rise to the 49-chromosome plant. If the assumption is correct that the second nucleus was fertilized by two sperms, we have in this case an instance of polyspermy in wheat.

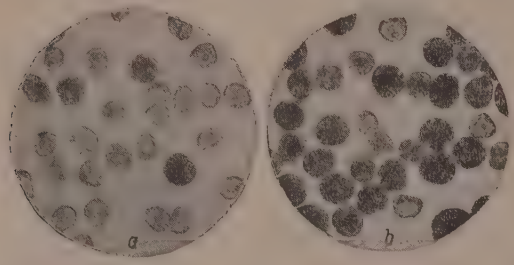

Fig. 5. Pollen: *a*—of the 35 and *b*—of the 49-chromosome hybrid.

In each one of the two cases in the present investigation when both plants of a pair of twins were normal diploids, they proved hybrid, i. e. it did not happen that one was hybrid and the other was not. This indicates that in the formation of diplo-diploid twin seedlings in our case, and possibly also in other cases, the maternal and paternal elements participate in equal measure.

The phenomenon of polyembryony is known throughout almost the entire plant world, and although, as a rule, it is encountered very rarely, the percentage of cases in which it is accompanied by chromosomal aberrations is very high, sometimes reaching 88% ([3]), from which it may be concluded that in nature polyploid forms may have arisen also in this way.

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GENETICS

AN ADDITIONAL METHOD OF STUDYING THE GENE ACTION

By M. E. NEUHAUS

(Communicated by A. A. Richter, Member of the Academy, 28. IV. 1938)

The brilliant works of Beadle and Ephrussi ([1–3]) proved the method of transplantation to be applicable to *Drosophila*. The applications of this method seem, however, to be somewhat limited. It is therefore desirable to look for some new methods of the study of the action of genes.

Feeding larvae of a definite genotype with crushed larvae and pupae of another genotype can be suggested as one of the possible methods. The effectiveness of this method is confirmed by the following experiments. About 2 g of crushed larvae and pupae of the normal *Florida* stock were put in several vials over-populated with *w^e cnb* larvae of different ages. The eye colour of freshly hatched flies from these vials was compared with that of flies raised under normal food conditions. In the first experiment 465 flies were obtained. Among these flies 10 individuals proved to have the *w^e cn* eye colour, 5—eye colour intermediate between *w^e cn* and *w^e*, 7—were pure

Adult *w^e cnb* flies were placed on 31.III on fresh food. About 1–2 g of crushed larvae and pupae was put on April 4 and 5 in the food

Date of emergence	Crushed *w^e cnb* larvae and pupae put in the food			Crushed larvae and pupae of the red eyed stock put in the food			Control (№ crushed larvae and pupae put in the food)		
	Eye colour of the emerged flies			Eye colour of the emerged flies			Eye colour of the emerged flies		
	w^e cn	intermediate between *w^e cn* and *w^e*	*w^e* or close to *w^e*	*w^e cn*	intermediate between *w^e cn* and *w^e*	*w^e* or close to *w^e*	*w^e cn*	intermediate between *w^e cn* and *w^e*	*w^e* or close to *w^e*
10.IV . . .	8	—	—	4	—	—	—	—	—
11.IV . . .	17	—	—	—	8	1	63	—	—
12.IV . . .	136	—	—	—	3	22	47	—	—
13.IV . . .	256	—	—	—	8	60	43	—	—
14.IV . . .	65	—	—	—	5	22	6	—	—
15—18.IV .	57	—	—	—	10	51	19	—	—
19.IV . . .	7	—	—	—	10	1	2	—	—

Florida flies, and 443 flies had the eye colour w^e or close to w^e. In the second experiment 1250 flies were obtained, among which 5—with the w^ecn eye colour, 34—with an eye colour intermediate between w^ecn and we, 12—were pure *Florida* flies and 1200 flies had the eye colour w^e or close to w^e. In the table the results of the third experiment are given.

These experiments show the effectiveness of the method of feeding larvae of a certain genotype with crushed larvae and pupae of another one and prove that it can be used as an additional method along with that of transplantation.

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PLANT PHYSIOLOGY

CHANGE OF CARBOHYDRATE AND NITROGEN CONTENT IN SUNFLOWER VIEWED WITH REGARD TO IRRIGATION

By A. S. KRUJILIN, V. I. SAMOILOV and M. S. SHESTIALTYNOV

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Carbohydrate-protein metabolism is the fundamental biochemical process among those which are taking place in a living plant.

Carbohydrates, being the first product of photosynthesis, not only predominate in the complex of organic matter, but also constitute the chief energy-bearing material, while proteins «are the immutable substratum of life processes—the heterogeneous medium» (2). Naturally enough the investigators have taken exceptional interest in the study of carbohydrates and proteins.

Karl Paech (5) pointed out that the more the plant is provided with carbohydrates, the less is the disintegration of proteins, because carbohydrates are first consumed in the processes of energy transformation.

Vasiliev and Vasilieva (1) inferred from their experiments with various wheat varieties that the plant, being watered, decreases its amount of monoses, while the amount of saccharose and hemi-cellulose is increased, which is in direct contrast to what may be observed when the plant is suffering drought.

Other investigators (4) have established that the ratio of nitrogen grows up in the leaves of sunflower until the latter starts the formation of head, whereupon it begins to lessen. In wet years, which are favourable for the nitrification processes in the soil, the leaves increase their amount of nitrogen.

The object of our investigations was to trace the dynamic of the carbohydrate-nitrogen metabolism in sunflower under the aspect of optimal irrigation. The research work was led by Prof. N. A. Maximov.

The experimental part of the field investigations was carried out in 1935 at the Ershov meliorative test-station on the left bank of Volga. On April 20 sunflower № 169 was sown in broken ground which had been plowed in fall. The sprouts appeared on May 8. Plots, 250 m^2. Irrigation consisted in overflowing the plots with water, which was let run along the furrows; each watering supplied 700—800 m^3 water per ha. The experiment embraced the following variants: 1) no watering, 2) one watering at the stage of head-formation (22.VI), 3) two waterings, on June 22 and July 17 and 4) additional observations made on thrice watered plants. The samples for analysis were gathered in the morning hours (at 7—9 o'clock), every 5—7 days, from the top (4—5 leaf from above), middle and lower (3 leaf from below, unwithered) whorls. The carbohydrates were determined after the Hagedorn-Jensen method for the content of monoses, disaccharides and polysaccharides separately; the test for total nitrogen was made according to Kjeldahl.

Discussion of Results. A very interesting picture was revealed when we were following up the dynamic of the content of soluble carbohydrates (monoses and disaccharides) in the leaves of sunflower. With reference to monoses the following data have been obtained (Table 1).

Table 1

Amount of Monoses in % per 100 g of Dry Matter

Whorl and variant	Date of sampling							
	22.VI	27.VI	10.VII	17.VII	22.VII	29.VII	6.VIII	13.VIII
Top (9th) whorl, no watering	3.22	5.46	7.74	5.33	5.98	5.48	6.69	—
Do, watered once on June 2	—	4.83	4.59	5.75	5.29	5.52	5.14	5.32
Do, watered twice on June 22 and July 17	—	—	—	—	4.46	4.50	5.43	5.02
Middle (6th) whorl, no watering	—	—	6.62	5.34	5.53	—	—	—
Do, watered once on June 21	—	—	4.90	5.41	5.59	—	—	—
Lowermost whorl, no watering	2.97	5.17	2.79	3.79	4.33	5.20	5.09	—
Do, watered once on June 21	—	3.72	2.97	3.32	3.78	2.57	5.25	—
Do, watered twice on June 21 and July 17	—	—	—	—	2.72	2.31	2.55	—

A definite regularity may be traced in the table; we see the amount of monoses to go up in the leaves of the watered plants in the direction from the lowermost to the top whorl. In plants watered once and especially in those watered twice the amount of monoses in all the whorls through out the vegetative period was, except single cases, found to be lower than in unwatered plants. This points to a more intensive outflow of carbohydrates on account of the plant tissues having better absorbed water. The intensive outflow of carbohydrates points in turn to the possibility of an enhanced storing up of organic matter, in particular, to a better accumulation of fat at the period of grain filling. By the end of vegetative period we find the leaves in the lowermost whorl of unwatered plants to contain a greater amount of monoses compared to watered plants which is probably due to a strong hydrolysis, taking place under the influence of dehydration and feeble outflow of carbohydrates. This fact has been observed in other variants too.

Let us examine the data on the dynamic of disaccharides (Table 2).

It may be seen from the table that whatever the whorl and variant the total amount of disaccharides in the leaves is greater than that of monosaccharides. It is moreover going up as the vegetative period approaches its end, while the amount of monoses remains stable showing a slight decrease by the end of vegetation. The increased ratio of disaccharides may be put down to their weakened outflow by the end of vegetation and to a reduced rate of convertion of monoses into disaccharides, which is accounted for by the lack of water in the leaves. This has in fact been supported by the observation of the water content in leaves which has been found to fall off abruptly by the end of vegetation in all the variants.

In every whorl the leaves of unwatered plants, as seen from Table 2, possess a greater amount of disaccharides compared to watered plants, all the more if the latter enjoyed a repeated watering. This may be accounted for by a feeble outflow of unwatered plants owing to their insufficient water supply.

A curious dependence was observed in the dynamic of disaccharides with regard to the second watering. Before the latter was done, the plants both of single and double watering variants showed no difference whatsoever in their behaviour. After the second watering we see the plants of the double variant to have notably reduced their amount of sugars in all the whorls which should not be considered as an abatement of their activity, since enhanced outflow and assimilation have been observed after the second watering too.

Table 2

Amount of Disaccharides in Leaves of Sunflower in % per 100 g of Dry Matter

Whorl and variant	Date of sampling							
	22.VI	27.VI	10.VII	17.VII	22.VII	29.VII	6.VIII	13.VIII
Top whorl, no watering . . .	6.50	6.22	9.01	6.32	7.39	8.00	9.93	—
Do, watered once on June 21	—	7.40	7.67	6.26	6.00	8.26	8.94	9.05
Do, watered twice on June 21 and July 17	—	—	—	—	5.25	6.94	8.45	8.82
Middle whorl, no watering . .	—	—	8.76	6.74	6.95	—	—	—
Do, watered once on June 21	—	—	5.86	6.49	6.92	—	—	—
Lowermost whorl, no watering	5.20	6.27	3.42*	5.69	5.26	7.56	9.03	—
Do, watered once on June 21	—	6.03	4.70	5.14	5.69	4.69	7.80	—
Do, watered twice on June 21 and July 17	—	—	—	—	3.85	4.80	4.90	—

* After rainfall.

This seems to bear evidence for the improved water supply, enhancing the synthesis of soluble carbohydrates into insoluble forms—starch (reversible «sugar reaction»). It is here that we face a phenomenon which is in the opposite to what has been pointed out by Lvov and Bereznegovskaya (3), who have observed an increase of soluble carbohydrates («sugar reaction») alongside of a reduced content of starch (hydrolysis) in the slightly wilting leaves of tobacco suffering drought. As to the dynamic of the starch, we have obtained the following data (Table 3).

Table 3

Ratio of Starch in % per 100 g of Dry Matter

Whorl and variant	Date of sampling							
	22.VI	27.VI	10.VII	17.VII	22.VII	29.VII	6.VIII	13.VIII
Top whorl, no watering . . .	9.06	6.53	9.41	8.05	9.47	9.68	—	—
Do, single watering on June 21	—	9.11	9.78	9.42	9.48	10.54	9.82	9.20
Do, double watering on June 21 and July 17	—	—	—	—	9.61	11.34	9.04	10.64
Middle whorl, no watering . .	—	—	9.62	8.17	7.85	7.85	—	—
Do, single watering on June 21	—	—	8.38	8.48	9.64	—	—	—
Lowermost whorl, no watering	8.51	9.05	8.98	7.84	7.36	9.81	10.98	—
Do, single watering on June 21	—	8.94	9.13	6.10	7.19	9.54	9.47	—
Do, double watering on June 21 and July 17	—	—	—	—	9.29	9.46	8.93	—

As seen from Table 3, the amount of starch is about 2 times that of monoses and exceeds the content of disaccharides 1.5 times. This holds true for all the whorls (except the top whorl in unwatered plants), variants and days of sampling. By the end of vegetation period the starch content goes up while it is slightly falling off during the stage of flowering. The enhanced content of starch is in full agreement with the reduced content of monoses (especially in the top whorl) at the second half of the vegetation period which points to the possibility of their being converted into starch.

As a rule, we have less starch in the leaves of the lowermost whorl than in those of the top whorl. This has already been pointed out by Lvov and Bereznegovskaya (3). The only exception are the unwatered plants as observed on June 27 and July 10. As to the middle whorl, its position with regard to the content of starch is intermediate between the upper and lowermost ones.

Comparing the amount of starch in top whorls we see the twice watered plants to be, as a rule, the best provided with starch, then come the plants watered once, while the plants which were not given water at all are the poorest in starch. The picture is opposite to what has been observed with regard to monoses and disaccharides.

Table 4

Amount of Total Nitrogen in Leaves of Sunflower in % per 100 g of Dry Matter

Whorl and variant	Date of sampling						
	27.VI	11.VII	17.VII	22.VII	29.VII	7.VIII	13.VIII
Top whorl and variant	4.75	5.12	4.93	4.84	4.36	3.15	3.0
Do, watered once on June 21 . . .	—	—	—	4.33	4.49	3.35	3.26
Do, watered twice on June 21 and July 17	4.42	4.91	4.67	4.20	4.82	4.15	3.57
Middle whorl, no watering	4.05	3.94	4.40	4.49	3.71	2.02	—
Do, watered once on June 21 . . .	—	—	—	3.99	3.84	2.65	—
Do, watered twice on June 21 and July 17	3.89	3.78	4.18	3.90	4.19	3.44	—

From the data of Table 4 it may be seen that before the stage of grain filling the watered plants have a greater amount of total nitrogen stored up in the leaves of the top whorl, as compared to unwatered plants. After the grains have filled, the relation is opposite. The enhanced ratio of nitrogen in the leaves of unwatered plants observed during the first half of vegetation should be put down to their poor assimilation power which resulted in a curtailed store of nitrogen und accordingly in a but feeble increase of dry matter.

As to the decrease of nitrogen in unwatered plants during the second half of vegetation, it may be accounted for by their earlier ripening (withering of leaves) which brings about an intensified outflow of nitrogen components to the seeds and their weakened inflow from the soil. The plants given water two times have more nitrogen stored up during the second period of vegetation, than when given once and especially when deprived of water at all.

Summary. 1. When optimal conditions of moisture are created by irrigation, the leaves of sunflower are increasing their ratio of disaccharides and polysaccharides and that of monoses and nitrogen which is an evidence of a reduced hydrolysis and enhanced synthesis. Thus, we face here a process which is quite opposite to what is observed under conditions of insufficient moisture (drought). The leaves of watered plants being better supplied with water, the total amount of soluble carbohydrates in them is lower, compared to unwatered plants, in which the synthesis into starch is not so intensive and a lesser bulk of dry matter is storing up. This is especially conspicuous in repeatedly watered plants.

2. As to the content of separate groups of carbohydrates and nitrogen, the top leaves are distinguished by higher indices which should be put down to their high assimilation power. This is the better expressed in the variants with repeated watering.

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PLANT PHYSIOLOGY

OPTIMAL LIGHT CONDITIONS FOR CULTIVATING *CINCHONA SUCCIRUBRA* PAV. AT SUKHUMI

By B. S. MOSHKOV and I. E. KOCHERZHENKO

(Communicated by N. I. Vavilov, Member of the Academy, 22. IV. 1938)

The *Cinchona* tree is native to mountain-forests of tropical South America. Its habitat is characterized by high humidity of air, frequent mists and cloudiness, a constant temperature within 16—20° C, and photoperiods with short 12-hour days. Under these conditions too, the crowns of the tree rarely reach the forest roof, and before they can do this they long remain at mid-height or in undergrowth. We should therefore not be surprised by the fact that this tree is a shade-loving one.

Adequate shading, based on the knowledge of the optimal light intensity for the life activity of the *Cinchona* tree, is necessary for its successful cultivation on commercial scale. On that ground we undertook experiments, in the summer 1937, on growing *Cinchona* cuttings under screens of 1, 2, 3, 4 or 5 layers of gauze or 1 layer of matting.

After the cuttings had taken root and attained the height of 5.5 cm they were transplanted, on May 15, to the field, 48 plants per plot with a density of stand 25×25 cm. The shading lasted from the day of transplantation until October 15, harvesting was done on November 15. Analyses for alkaloids were made by O. Yefimenko in the biochemical laboratory of the All-Union Institute of Plant Industry.

The principal results of the experiments referring to the yield of vegetative mass and the amount of alkaloids extracted from it may be seen in Fig. 1 and Table 1.

The average weight of *Cinchona* plants grown for 6 months under 3 layers of gauze amounted to 330 g (raw) and 66 g (dry). The yield of alkaloids per unit of dry weight proved also to be the highest in plants shaded with three layers of gauze. The leaves and roots of these plants gave an amount of alkaloids well above that yielded by plants grown under denser or thinner screens. Only the stems contained less alkaloids compared to the plants under thinner screens. This is traceable to the fact that the plants under three layers of gauze had more strongly developed the tissues of wood, which contain no alkaloids. Their ratio of alkaloids referred to the total mass of the stem was therefore reduced. We have thus to state that in the three layers of gauze variants the increase of vegetative mass and the synthesis of alkaloids were going on more energetically than in other variants. Consid ring the data obtained in that variant, we may conclude that 1 ha of *Cinchona* plantation with 100 000 plants should yield a minimum of 100 kg

alkaloids, or 10 kg of crystalline quinine, taking for granted that the latter makes 10% of the total content of alkaloids.

In Table 2 are summarized the data on temperature, humidity of air and intensity of light with reference to different screens. The temperature of the soil was the same in all variants and is therefore not referred to in the table.The temperature of the air under three layers of gauze was by 0.8°

Fig. 1. Shade-grown 7-months old plants of *C. succirubra*; screened with 1,2, 3, 4, 5 layers of gauze or matting. Photo taken on November 17, 1937.

lower than under direct sunlight, yet it was nearly as far from the optimum, if we take for the latter the average temperature of the country the *Cinchona* is native of.

The temperature of the air was lowest under the mat (reduced by 3°), yet the yield in this variant was far below that, obtained under three layers of gauze. We have thus to conclude that the favourable conditions under

Table 1

Yield of Vegetative Mass (Inclusive of Roots) and Alkaloids Obtained from an Average of 48 7-Months Old Plants Harvested on November 15, 1937

Density of shading	Height in cm	Weight in g			% of total weight of dry matter				Weight in g (dry)			Content of alkaloids in %			Yield of alkaloids in g		
		Total															
		raw	dry	inclusive of alkaloids	Leaves	Stems	Roots	Alkaloids	Leaves	Stems	Roots	Leaves	Stems	Roots	Leaves	Stems	Roots
1 layer of gauze . .	23.5	70	19.0	0.24	49	29	22	1.26	9.3	5.5	4.2	0.66	1.62	2.22	0.061	0.089	0.093
2 layers of gauze . .	40.5	185	39.6	0.57	42	36	22	1.42	16.6	14.3	8.7	0.75	1.63	2.41	0.125	0.233	0.210
3 layers of gauze . .	70.5	330	66.0	1.03	41	38	21	1.56	27.1	25.0	13.9	0.89	1.51	3.00	0.241	0.377	0.417
4 layers of gauze . .	69.5	235	54.2	0.70	43	40	17	1.29	23.3	21.6	9.3	0.84	1.22	2.56	0.196	0.264	0.238
5 layers of gauze . .	46.0	156	29.5	0.37	51	29	20	1.23	15.0	8.5	6.0	0.78	1.45	2.19	0.117	0.123	0.131
Matting . .	34.8	100	23.8	0.26	58	25	17	1.08	13.8	5.9	4.1	0.54	1.45	2.43	0.075	0.086	0.100

Table 2

Changes in Principal Meteorological and Light Conditions under Different Screens in First Clear Days of September 1937

Variants of shading	Midday temperature	Midday humidity of air		Illumination intensity in % to direct sunshine						Note
				Morning		Day		Evening		
		absolute	relative	7 h. 30 m.	8 h. 30 m.	12 h.	14 h. 30 m.	17 h.	19 h.	
1 layer of gauze . .	29.6	18.5	59	20	34	72	65	59	22	Out of screen temperature in the midday 29.8°. Absolute humidity 16.6, relative—53
2 layers » » . .	29.2	19.1	64	10	16	51	40	34	13	
3 » » » . .	29.0	19.1	64	7	12	37	31	18	6	
4 » » » . .	28.8	19.1	64	5	9	24	23	12	4	
5 » » » . .	28.2	19.7	70	3	6	16	12	8	2	
Matting	25.8	21.0	84	1	2	9	7	5	1	

three layers of gauze were not caused by the temperature. The absolute and relative humidity of the air was nearest its optimum under the mat. Under three layers of gauze the humidity was the same as under two layers, yet the yield was considerably higher. Consequently, air humidity was not decisive for the results of our experiments either. In spite of the temperature and humidity of the air being nearer to the optimum for the life of *Cinchona* in the mat variant, the latter gave owing to deficiency of light only one-third as high a yield as that obtained under three layers of gauze. Under three layers of gauze, where the yield proved to be the highest, the intensity of illumination was only one-third of that on an open plot. The light intensity under the screens was subject to irregular reductions. In the midday hours it was reduced to one-third under three layers of gauze, while in the morning and evening hours to $^1/_{14}$—$^1/_{15}$. In the morning and evening sunlight is not so intense as at the height of day, that is why any screen whatever presents a stronger obstacle at these hours. Thus, alongside of changes in the intensity of illumination under the screens the daylength seems to vary too owing to the light being curtailed in morning and evening hours. We know indeed that for the photoperiodic effect to be brought about there is no need of «absolute» darkness. Light being subject in the course of day to gradual qualitative and especially quantitative variation, i. e. changes of intensity, is perceived by the plants as physiological darkness after it has attained some limiting value of its intensity. This limit is different for different plants. In this connection it seems at place to quote a table from a paper by Moshkov (1) which shows the effect of different photoperiods on the yield of vegetative mass and the content of alkaloids in the leaves of *Cinchona* seedlings (Table 3).

The highest yield of vegetative mass belongs to the 10-hour variant, while the largest amount of alkaloids was observed in plants given 8—9 hour days. These results approach to what we have obtained under three and four layers of gauze.

All the aforesaid leads us to the following conclusions:

1. The irregular intensity of illumination under the forest roof, which has been changing unevenly in the course of day, should be considered one of the factors which have determined the evolution of the genus *Cinchona*

Table 3

Photoperiodic Response of Seedlings of *Cinchona succirubra* Pav. Observed in 1936

	Daylength in hours								
	15—11	13	12	11	10	9	8	7	6
Average raw weight in g.	14.0	21.5	29.5	52.3	55.4	43.5	37.8	26.4	21.3
Average raw weight in %	100	153.6	210.7	373.0	396.0	310.0	270.0	188.0	152.0
Content of alkaloids in % of dry weight .	0.58	No data	0.54	0.61	0.68	0.85	0.87	0.81	0.72

and told upon its biology. This accounts for the artificial shading being necessary to create optimal conditions for the life activity of the *Cinchona* when this tree is being cultivated in field plantations, and to secure its positive response to photoperiods of 10—11 or 9-hour daylengths, which should be substituted for those of 12-hour daylength.

2. Carrying on further investigations with the aim of clearing the question as to the degree of shading in different months and even at different hours, we must look for cheaper shading material in order to reduce to minimum the expenditures on the culture of the *Cinchona* tree.

In selecting the most valuable varieties for clonal reproduction, i. e. those superior in their yield of vegetative mass and high content of alkaloids, it is necessary to give special attention, on the one hand, to cold-resistant forms, for the undergrowth cultures and, on the other, to the selection of light- and heat-resistant specimens, in order to meet the requirements set by the summers of our subtropics.

As soon as we have both kinds of clones at our disposal and put them under most favourable conditions with regard to illumination, nutrition, humidity, care, etc., we shall certainly be able and we ought to obtain the maximum yields from the *Cinchona* tree, which will make this crop not only possible but economically valuable under the conditions prevailing in this country.

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ZOOLOGY

MACRO- AND MICROSTRUCTURE OF THE METACARPUS BONES IN SOME SHEEP-BREEDS

By E. G. ANDREEVA

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The question as to the structure of bones of domestic animals, their variability, the inheritance of some peculiarities, remains as yet obscure. However, the character of the development and structure both of skeleton and separate bones make it possible to form an idea about some peculiarities of the «extérieur» of animals which are responsible for their meat qualities (15).

Many investigators were concerned with the question of bone structure, their attention being focused on some particular side of the problem. Some of them were studying external morphological peculiarities of the bones and their measurements [Brauner (2), Gromova, Josseliani (7), and others]. Others investigated the microstructure (Haverl's system, the structure of cells, the system of Haverl's lamina and the fibrils of bone lamina) [Gebgardt (4), Haussen (5)]. A number of students [Wolter (13), Reymond (11), and so on] took interest in the physical properties of bones. Much work has been done to ascertain the chemical composition of bone tissue (6). Each of these studies is dealing with an individual bone or group of bones under some definite aspect. The great merit of Bogdashev (3) and Schabadasch (12) (especially of the latter) consists in that in their work they make an attempt to show the inseparability, the deep unity of external and interior structure. They assume that the study of bones has to involve both the macro- and microstructure, and only a deep understanding of the exterior and the interior connection of elements visible and invisible can give a correct idea of the whole.

This note is meant to characterize the micro- and macrostructure of the metacarpus bone in some sheep-breeds. We are in it endeavouring to outline the metacarpus bone of a separate breed, describing its form and some traits of its microstructure, and to trace the connection between this part and the whole skeleton and habitus of the breed under investigation, so as to make their unity conspicuous.

The metacarpus bone reflects better than any other element the character of the whole skeleton. A number of zoo-technicians point out that this bone may be considered as the criterion of the solidity of the skeleton.

Chervinsky (16) gives data characterizing the metacarpus as a part of the skeleton which among all other bones is the least liable to changes under the influence of individual conditions of existence. Hammond is inclined to explain this fact by the precocity of the metapodiae: their development is essentially completed as early as at the embryonal period, prior to all other extremity bones.

Natusius ([10]), Haussen ([5]), Andreeva ([1]) have shown that the general form, the cross-section, the wall thickness, the number of Haverl's canals per unit of the cross-section area and the finest structure of the Haverl's laminae widely vary with the tendency of breeding and the external conditions these animals are raised under. In most cases one may trace the correlative connection between different structural elements and the performance of definite sheep-groups (meat-sheep, wool-sheep).

The present work is a small part of the studies carried on in Askania Nova on the characters of new breeds of Hampshire-Tzigais (their bodily constitution was studied by Prof. Bogoljubsky).

The study od separate elements of the metapodium structure of these breeds gave the following results:

1. The m e t a c a r p u s in Hampshire and Tzigais differs as to the general form. The Hampshires have a short, broad-boned metacarpus. The Tzigais have it somewhat lengthened and narrowed.

The indices of the relation between width and length, characterizing in a general way the form of the metacarpus bones, in the Tzigais are 11.5 and 12.3; in the Hampshires—13.1 and 14.75; in the cross-breeds—11.7 and 14.5. Thus, we see that the form of the metacarpus in one cross-breed is nearer to Tzigais, in the other—to Hampshires.

The oval of the cross-sawing in the Hampshire bone shows the figure of an irregular ellipse, elongated in the lateral direction and flattened in the front-back direction. The cross-section of the Tzigais bone is rounder. The indices (ratio of the front-back diameter to the lateral diameter)show these differences verly clearly. For Hampshires they are 63.9 and 65.6; for Tzigais 71 and 73.3; for cross-breeds 66.6 and 67. The indices of cross-breeds point to the intermediate position the latter occupy according to this character between Hampshires and Tzigais.

To these characters of macrostructure we must add the characteristic of the thickness of bone wall of the diaphysis.

It is well known that wild sheep have a thick-walled bone, while Shropshires and Hampshires have thin-walled ones. The wall thickness in Merinos varies greatly, yet it may safely be called middling. Consequently, the relative wall thickness in meat-breeds exceeds that in wool-breeds.

This fact finds support in our data too: the index in Hampshires (ratio of wall thickness to average diameter) is 36.5 and 37.7; in Tzigais—40.9 and 47.9; in cross-breeds—31.9 and 36.5. This time the cross-breeds show a lower index than Hampshires. They prove to have a thinner bone wall, instead of assuming an intermediate position, as should be expected.

2. The b l o o d s u p p l y of the compact part of metacarpus bones in both domestic sheep and wild representatives of *Ovis* is characterized by different sizes and number of Haverl's canals. Calculations made according to the method of Maligonov ([8]) and Bedniagin authorize us to assign the Hampshires the first place as to the number of Haverl's canals per unit area, the Tzigais—the last one, while the cross-breeds assume an intermediate position.

Observation shows that there exists a correlative connection between the size and the number of Haverl's canals; wild forms possess a larger number of canals, but the diameter of the latter is smaller, whereas cultured forms have a smaller number of larger canals. It is therefore preferable to characterize the general blood supply of the compact part of the bone by means of a figure, expressing the area occupied by the net of blood vessels per unit of bone area. The results of such calculations show this area larger in Hampshires than in Tzigais; in cross-breeds these indices are still smaller. The study of the metacarpus of wild sheep and of some breeds of domestic ones after

this method enables us to affirm that the metapodiae in more mobile forms (wild species, hill-breeds of domestic sheep, and so on), as well as those in Hampshires, are better supplied with blood than those in Merinos and other wool-breeds.

Richer blood supply of Hampshire metapodia may be due to the higher nurishment of the whole body in meat-breeds. At the same time our data show that wild sheep as well as mobile breeds of domestic ones are characterized by the same increased blood supply. Thus, the activization of the function of movement may obviously account for the increase of blood supply. The disclosure of the causes underlying these phenomena necessitates the study of a large material, taking due account of the physiological, functional, historical and natural peculiarities of the breed under investigation.

3. The finest structure of bone tissue. It is well known that Haverl's systems consist of laminae, disposed concentrically around Haverl's canals. These laminae consist of bunches of finest fibrils. The slant of the fibrils differs for different laminae, but within the same lamina it remains uniform. Some authors admit the existence of a number of regular connections between the incline of the fibrils of a given character in most laminae, and the character of the function of the animal's locomotion [Gebgardt, Haussen, Zeddies (14)].

The easiest method to determine the direction of the fibrils is the study of a microscopic section in polarized light. This method is based upon the ability of the bone to give a double refraction in polarized light.

The method suggested by Gebgardt enabled Haussen and Zeddies to study the structure of the metapodiae in domestic sheep and horses. They found that the metacarpus bones in more active animals (fleet horses and primitive sheep) are mostly characterized by a parallel disposition of fibrils, whereas slower moving animals (pacer horses and cultured meat-sheep) possess mostly a circular disposition.

This analysis of the finest bone tissue of the metacarpus in the sheep-breeds under investigation shows that Tzigais have a higher number of osteons with paralelly crossed fibril disposition. The Tzigais are sheep of good old culture, meant for long journeys, very light footed. These data confirm the statement made by Haussen and Zeddies that Haverl's systems with parallel fibril disposition prevail in active animals. The Hampshires studied show different correlations: in one specimen the number of osteons with parallelly crossed fibril disposition and with circularly crossed fibril disposition was 47 and 34.7% respectively. The second specimen had 37% of osteons with parallelly crossed fibril disposition and 27% osteons with circularly crossed ones*. Thus, the prevalence of osteons with parallelly crossed fibril disposition is still observed, although immaterial.

The indices characterizing the finest structure of the metacarpus bone of the cross-breeds are different. One of them shows a distinct prevalence of osteons with a parallelly crossed fibril disposition (66.0% and 14.6% osteons with circularly crossed), very much like the Tzigai. The other specimen has 46.6% osteons with parallelly crossed fibrils and 38.9% osteons with circularly crossed. This correlation is similar to that observed in Hampshires.

Yet, unexpectedly enough, the cross-breed whose metacarpus showed macrostructural characteristics reminding us of the Tzigai possessed a structure of the finest bone tissue closely approaching that of the Hampshire. The second specimen whose metacarpus bone exhibited Hampshire-like macrostructure, displayed indices reminding of the Tzigai as to the structure of the finest bone tissue. Only a study made on a large scale may answer

* The remaining 36% are osteons with combined type of fibril disposition.

the question whether the non-correlation of the macro- and microstructure of the same bones is a casual individual irregularity, or whether it is a phenomenon dependent on the inheritance of some characters and the non-inheritance of others.

This article does not pretend to give firmly established conclusions since the studied material was far too limited. Yet, the results obtained trace the way to further study of questions bearing upon the variations of skeleton elements in connection with the conditions of existence, breed characters and cross-breeding.

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DEVELOPMENT MECHANICS

GROWTH OF EXTREMITIES IN TADPOLES ON HETEROTOPIC TRANSPLANTATIONS

By A. I. IRIKHIMOVICH

(Communicated by I. I. Schmalhausen, Member of the Academy, 12. IV. 1938)

The question of the relation between the processes characteristic of the metamorphosis in the amphibiae has more than once engaged the attention of investigators. In particular Champy (3) worked out the problem of the basic significance of the phenomena of proliferation, while Blacher (1) considered them as depending on the phenomena of resorption. Both authors started with the assumption that intensive proliferation in the growing organs corresponds in time with the process of resorption in other organs. However, Etkin (4), Irikhimovich (5) and Woitkewitch (7), in studying natural metamorphosis, found a decrease in the intensity of growth at the culminating stage of transformation (a period of intensive resorption). In his last work Efimov assumes that the resorption of some and the proliferation of other organs depends on their specific structure. Blacher's conception is supported by the latest experimental data obtained in his laboratory (2). Transplanting the fore legs of tadpoles to the tail (region of resorption) and to the back, the authors noticed the difference in the growth of the extremities transplanted to the tail and explained this fact by the closeness of the source of resorption. It should, however, be pointed out that the growth of the transplanted parts was estimated only by measuring the 4th digit, and not of the whole extremity. Moreover, the observations were performed within a very short period of time, a few days, 1—2 days out of which were necessary for the ingrowth of transplantates. Formerly, Schubert (6), transplanting the anlage of the extremity to the tail of the tadpole and observing the life of the transplantate till the completion of the transformation of the recipient, stated that the transplanted extremity did not reach its normal size. Therefore it seemed to us necessary to review the question of the growth of the extremity in heterotopic transplantations.

The experiments were performed on tadpoles of *Pelobates fuscus* and *Bufo bufo*. The hind extremities, at the stage of the formation of anlage of digits, were transplanted to tadpoles of the same age. In some tadpoles the transplantation was performed in the back (in the region of the shoulder) and to some in the middle of the tail. Each group consisted of 15—20 specimens. In *Pelobates fuscus* the experiments differed in that at the moment of transplantation the recipients of one series were at the first stage of development [after Blacher (1)], while in the second one they were not older than the third stage.

In the majority of cases the transplantates grew in well. Only during the first days after operation a reddening and partial resorption of the distal end, especially frequent in transplantations to the tail, could be noticed. Every six days the length of the transplanted extremity was measured, till the completion of the metamorphosis (in *Pelobates fuscus*, for 48 days since transplantation, and in *Bufo bufo*, owing to more rapid development, for

18 days). The results of the experiments, expressed in average values characteristic of the growth of the transplanted extremities, are tabulated below.

An analysis of this table shows that the growth of extremities on the back and on the tail is analogous. In view of full agreement between the figures of repeated measurements there was no occasion to calculate the indices of rate and intensity of growth. It is important to note that the results are the same, irrespective of the stage of the recipient (the two stages of *Pelobates fuscus*) and the time of their transplantation. On the completion of the resorption of the tail, the extremities «crept over» to the trunk, as in the experiments of Schubert. By the end of the experiments all the extremities reached the same size and were equally developed (Fig. 1).

Fig. 1. The tadpole *Bufo bufo* with extremities transplanted to the back and tail (18 days after transplantation).

The data thus obtained show that the rate of growth of the extremities does not depend on the locus of transplantation. In particular the transplantation of the extremities to the tail does not cause any increase in the intensity of growth. Thus, the assumption of the growth of the extremities as depending on the general condition of the development of the tadpole is again confirmed. The basic rôle is played here by the hormonal factors (thyroid gland, hypophysis), whose part in the determination of the character of the growth of the extremity was discussed in the previous communication ([5]).

The Growth of Extremities Transplanted to the Back and Tail of Tadpoles (length in mm)

Days passed since transplantation	*Pelobates fuscus*				*Bufo bufo*	
	Transplantations to the I stage		Transplantations to the III stage			
	Back	Tail	Back	Tail	Back	Tail
0	1.5	1.5	1.5	1.5	1.0	1.0
6	3.0	2.8	3.2	3.4	2.6	2.2
12	3.8	3.4	6.0	6.5	3.8	3.4
18	4.7	4.3	8.4	8.4	4.8	4.8
24	5.8	5.3	9.8	9.3	—	—
30	6.3	5.8	10.2	10.0	—	—
42	6.9	6.5	10.9	10.8	—	—
48	7.1	7.0	11.2	11.0	—	—

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